Future Pathways feedback from Björn Oback

I have been employed as a scientist at AgResearch since 2000. I further hold Adjunct Associate Professor positions at University of Waikato and University of Auckland, as well as being an Associate Investigator at the Maurice Wilkins Centre.

I first provide an overview that summarises the symptoms and causes of the CRI malaise, specifically at AgResearch, based on my reading and experience (part 1). These underlying assumptions are presented to frame specific feedback on how to reform a future science system in NZ (part 2).

PART 1. Diagnosis of the malaise and need for change.

Indicators that the science system is in trouble

1. **Insufficient funding**. The amount of money that countries invest into research has stagnated or declined in real value measured against inflation or has even been slashed in absolute terms [1]. Consequently, success rates for grant applications have decreased to <10% in some countries, which means that scientists need to submit an average of ten or more proposals to have one funded. This forces many of them to spend a lot of their time and energy writing grants instead of thinking about or doing research [2].
2. **Reproducibility crisis.** Poor reproducibility in many science areas [3, 4] has come to the attention of government [5] and mass media, leading to mistrust in science-based decisions.
3. **Depression among scientists** (up to 60% of graduate students feel overwhelmed, exhausted, hopeless, sad, or depressed nearly all the time and 10% contemplated suicide (doi: 10.1126/science.caredit.a1400031). This also leads to "doused passion", especially in young scientists with uncertain career pathways and poor mentoring [6].
4. **Hypercompetition** for resources and positions suppresses the creativity, cooperation, risk-taking, and original thinking required to make fundamental discoveries […] The system favours those who can guarantee results rather than those with potentially path-breaking ideas that, by definition, cannot promise success [1]. Increasing competition for funding and positions is eroding the integrity of science and is leading to increased research misconduct by desperate researchers [1]. The competitive funding model, combined with the splitting up of funds for science into increasingly smaller 'pots', has resulted in the cost of bidding for the funds (including scientist's and bureaucrat's time) often exceeding the funds being sought.
5. **Prevalence of translational research**. A worrying trend has been the major shift of emphasis toward funding research with direct practical applications. The relationship between public sector funding bodies, academic researchers and the wider public is being reorganized in terms of **customer-contractor relations** [7]. Fetishizing the outcomes of research, in terms of new findings and results, favours those ways of practicing science most likely to generate short-term commercial and economic benefits, which discounts other reasons for engaging in academic inquiry [7]. These changes are designed to make academic research more responsive "to the demands of research customers in government and industry" [8].
6. **Neglected basic research**. This devaluates knowledge as an abstract good. If science is funded solely for economic gains, then what good is knowledge that has no immediate practical benefits? Even when fundamental research is explicitly defended, it is still done based on potential long-term economic benefits, which devalues its intrinsic importance.

7. **Inflated overheads** to cover the so-called indirect costs of research, including construction and the maintenance of buildings, utilities, and administration [9]. Pouring money into buildings at the expense of the people on whom the business depends, indicates poor management rather than a particular operational model. Indeed, as a consulting firm concluded after inspecting the institutions of higher learning, "In no other industry would overhead costs be allowed to grow at this rate—executives would lose their jobs" (http://www.bain.com/Images/BAIN_BRIEF_The_financially_sustainable_university.pdf)
8. **Flight of talent.** Reluctance of new talent to join science, which is perceived as difficult and paying poorly.

The overall condition has invoked the image of the Titanic approaching its iceberg [10]. Treatment of the malaise requires correct diagnosis, which is summarised below. The root cause of the malaise appears to be the decision to run science as a business, exacerbated by the perpetual growth myth, which has also prompted an imbalance between the available financial resources and scientists. This approach has failed and needs reforming.

Diagnosis of the root cause for trouble in the science system

1. **Businessification of science**, i.e. the attempt to apply business models of operation to basic science. The constant use of economic arguments in defence of research funding perpetuates a rarely articulated but implicit misconception that the natural sciences should be subservient to economics in the pecking order of intellectual authority. This view persists despite the global economy being only a small part of the natural world and therefore constrained by physical and biological processes, an understanding of which is provided by the natural sciences. On an operational level, this misconception leads to **dualisation** which strengthens the divide between insiders in secure, stable employment and outsiders in fixed-term, precarious employment (aka "them vs us" mentality) (http://blogs.lse.ac.uk/impactofsocialsciences/2013/12/11/how-academia-resembles-a-drug-gang/). The outsiders now increasingly include scientists. During the past three decades, the number of administrators at the institutions of higher education grew 16 times faster (369 to 23%) than that of tenured or tenure track faculty, the salaries of top executives grew two-to-three times faster than that of professors, and the institution of tenure, which provided job security for faculty, has been steadily driven into extinction (http://www.aaup.org/reports-publications/2013-14salarysurvey). The self-organizing and self-maintaining system of "Science, the Endless Frontier" was replaced with the chain of command. Directors of scientific institutions rebranded themselves as CEOs with fancy titles (e.g. STLs, ICELs, SOLs, ARDs) assigned to their subordinates. This change in appearances and the underlying thinking reflects a wish to run scientific institutions as a business. CRIs became **dysfunctional hybrids** or **pseudo-businesses**.

2. **Perpetual growth myth.** Acceptance of perpetual economic growth as the ultimate good poses a major hurdle [11]. The idea of infinite economic growth clashes with our most basic scientific understanding of the physical world. The question is whether it is prudent to call for more funding by promising more economic growth in return when continued expansion of the economy is contradicted by scientific evidence that this is not sustainable. Thus, advertising science as a driver of economic growth is a long-term losing strategy.
   There is also the matter of what the mission and core values of science are: namely to uncover how the world works in an objective way. This is a proud tradition built over centuries; modern science is the intellectual heir to millennia of human efforts to understand the natural world. It is a good idea to take an equally long-term view of the future. Doing so eliminates most justification for advertising science as a driver of economic expansion. The obvious first step is to raise awareness and achieve unity among scientists

themselves. As a community, scientists should abandon the practice of advertising the economic benefits of scientific research and clearly communicate to the rest of society the physical limits to growth.

It is easy for scientists to forget that the majority of the population does not see the world as driven by the laws of physics. Most political and industry leaders have backgrounds in business-related field or the humanities with little training in the natural sciences. As a result, their worldviews center around relationships between humans. This disconnect is acute in the field of economics. Mainstream economists—even the more environmentally aware among them [12] — have refused to accept the existence of limits to economic growth, invoking instead the supposedly infinite powers of the free market and human ingenuity to overcome environmental limitations. Alternative approaches, such as ecological economics [13], have been marginalized.

3. **Imbalance between money and the number of scientists.** This follows from the assumption that the research system will expand indefinitely. We are now faced with the stark realization that this is not the case. "The current system is in perpetual disequilibrium, because it will inevitably generate an ever-increasing supply of scientists vying for a finite set of research resources and employment opportunities" [1]. The assumption that something tangible can expand exponentially endlessly is the foundation of market bubbles and commonly associated with crowd behaviour, not with outstanding analytical minds.

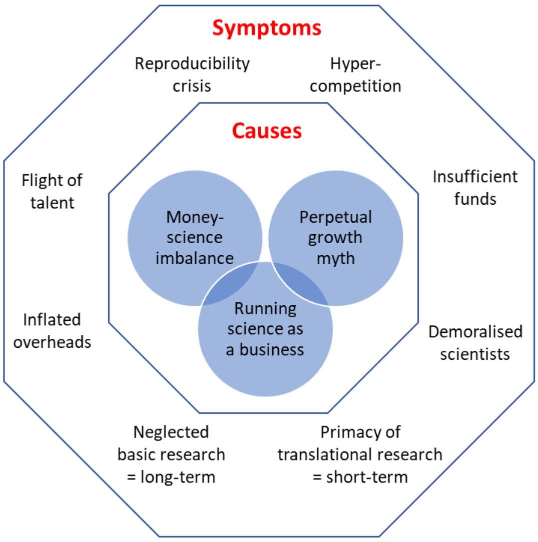

Figure 1. Symptoms indicating that science is in trouble (outer ring) and causes for the malaise (inner circle). Details in text.

PART 2. Feedback - Executive summary

Research Priorities

- Scientific research should not be placed under an operating agency whose paramount concern is anything other than scientific research
- Basic science needs protection.
- Do not align all scientific research with societal expectations
- Embrace uncertainty
- Do not expect investments into science generate technical innovations in the short term

Funding

- Increased base grant funding
- Reduce onerous bureaucratic functions
- Greater transparency around funding decisions

Institutions

- Stop 'businessification' of science
- Science organisations should be science-led
- Flatten the hierarchy
- Replace 'Yes' People at the Executive level
- Focus on the core purpose of science

Research workforce

- Don't call science and technicians "workforce"
- Inspire excellent scientists
- A base grant would make science a more attractive career choice
- Stop treating young scientists as cheap labour
- Empower the next generation of scientists
- Close the pay gap and implement pay transparency
- Enable researchers to perform their own cost–benefit analyses before applying for a grant

Research infrastructure

- Government needs to take responsibility for maintaining major plant, equipment, research facilities and research farms that are national assets

My submission follows the structure of the Green Paper. It provides specific feedback on what needs to be retained and enabled in a future system.

1. RESEARCH PRIORITIES

Question 3 **Scientific research should not be placed under an operating agency whose paramount concern is anything other than research**. Research will suffer when put in competition with operations [14]. To put it in contemporary terms: if earning money gains priority, and the director of a scientific institution becomes its Chief *Operating* Officer, basic research suffers. From the operational perspective, a patent related to medicine can bring millions of dollars to the institution, while wondering why petunias have colored patches may appear to waste much-needed resources (to note, petunias led to the discovery of RNA interference, a breakthrough that affected many areas of biotechnology). From the operational perspective, funding from the pharmaceutical industry is a gift from heaven, but this gift comes with an implied or explicit focus on medicine-related research.

Basic science is under threat and needs protection. Biological science is increasingly aimed toward solving specific medical problems such as Alzheimer's disease, cancer, and diabetes. These important health issues represent serious challenges facing society, but are they best addressed by solely focusing our efforts at correcting single diseases? Repeatedly, the solutions to medical challenges have rested on the foundation built by curiosity-driven basic science, with human health benefits only emerging over decades. Recently, disparate lines of research in virology, structural and RNA biology that seemed interesting mostly to basic scientists have now become the foundation of SARS-CoV-2 vaccines that are saving millions of lives. We cannot afford to abandon such efforts.

Basic science needs funding for fundamental discovery without being defined or confined to a particular goal. Launching theme-focused applied research institutes carries a risk because their structures do not typically include a paired mission for graduate and postgraduate education and training. This highlights the need for universities to strengthen their commitment to fundamental discovery biology, where science is pursued with no disease or particular endpoint in sight. To that end, academic institutions need visionary leaders who can navigate challenging funding climates while preserving curiosity-driven basic science. History has shown that important discoveries come from unexpected places and odd juxtapositions that are based upon deep understanding of biology. In fact, analysis of 28 "transformative" drugs approved by the FDA between 1995 and 2009 revealed that 80% of these medicines are traced back to basic science discoveries, many of which took place decades before realizing that the work had implications for a medical breakthrough [15].

Do not align all scientific research with societal expectations. History shows that this is to the detriment of science's prime mission of discovery. Because virtually all scientific research elevates our understanding of human nature and of the natural world, the relevance for society from any scientific project is fundamentally at a higher level than simple, practical applications. Even then, it is still just a matter of time until nearly all knowledge becomes useful and can be applied to new technologies: innovation is well entrenched in scientific practice.

Embrace uncertainty. We must keep looking for the unexpected to create the conditions for discovery. Helga Nowotny, the former President of the European Research Council (ERC): "The beauty of science is that it constantly plays with uncertainty. What the scientist is really trying to do is to discover something that he or she is not looking for, but is clever enough to recognize its importance when it appears" (https://www.youtube.com/watch?v=4vQd3pdH8tM). While the public likes certainties and turns to science for answers and the truth, science thrives in uncertainty.

Do not expect that investments into science generate technical innovations in the short term. It is impossible to turn every scientific advance into technological innovation because the requirements of discovery or innovation are different and sometimes even opposite. Instead, we should heed the idea that inspired some of the world's strongest economies for more than 50 years, eloquently described by Bush in 1945: "Basic research leads to new knowledge. It provides scientific capital. It creates the fund from which the practical applications of knowledge must be drawn […] Today, it is truer than ever that basic research is the pacemaker of technological progress […]" [16].

3. FUNDING

Question 8 The current competitive funding system largely fails in reliably ranking proposals for science quality [17]. Hence, it represents a strikingly inefficient lottery [18]. In many cases, grants provide a negative net return, where the costs of the applicants' time invested in the proposals exceed the granted funding [19].

Increase base grant funding [20]. The impact of base grants would depend on their size relative to the running costs of the organisation and how it was managed within the organisation. Increased base funding of future research institutions is a promising approach towards stability and resilience of both individual researchers and future institutions. We note that full salaries are included in CRI grant applications to external (e.g., Endeavour) and internal (e.g., SSIF) funds and that this is not the case for universities. So, if a CRI scientist's grant applications fail, the affected researchers and technical staff's jobs are placed at risk. A base grant model would provide stability by paying for both FTEs and infrastructure. Base grants which are guaranteed for reasonable lengths of time (6-10 years) and inflation-adjusted, would support improved organisational science and workforce planning. Greater funding security would allow organisations to invest in longer term research than the current short term funding rounds allow.

Reduce bureaucratic functions associated with competitive funding and its allocation. Grant proposals are too long and need to be significantly reduced to reduce the preparation costs and workloads [21]. Proposal requirements could be halved. In business, you quote a price, you say what you will do and if agreed, get onto it. The main project cost is doing the work. Imagine providing a customer a quote many pages long and then every month having to report pages and pages more on where you're at with it. Your overheads would be massive, and you would be bleeding money.

Foster transparency around funding decisions. The transparent review process adopted by open science journals serves as a template how grant applications should be evaluated [22]. This includes full disclosure of score cards, reviewers (with consent) and relevant metrics affecting grant success.

4. INSTITUTIONS

Question 10 **Stop businessification of science**, i.e., applying business models of operation to basic science. i.e. attempt to apply business models of operation to basic science has failed. On an operational level, this idea led to **dualisation** or "them vs us" mentality. It resulted in scientists being viewed as a "workforce" (or "engine room") by their superiors, the administrations of the institutions. Accordingly, top administrators, often with PhDs, now officially call themselves the leadership to emphasize that they no longer merely manage the institution to support research, but lead scientists, which implies telling them what to do. The leadership includes administrators who supervise finances, information technology, recruitment, public affairs, buildings and grounds, and other parts of the infrastructure, which means that the people whose job previously was to *serve* scientists are now leading them. With all due respect to these much-needed services and their providers, this change does put the cart before the horse, a rearrangement that stalls both.

Science organisations must be science-led. Top administrators (for finances, IT, HR, government affairs, infrastructure, strategy) are now considered the 'leaders' in our CRIs. Instead, we should develop R&D institutes bottom-up with a directorate of top-level representatives that are high-calibre principal scientists. We should ensure that top earners within the institute bring in more money than they cost as in the case of Directors at other top research institutes who lead and secure major grants (e.g., Maurice Wilkins Centre CoRE, Max Planck Institutes). Future institutions should be led by scientists who understand the need for continuity and who can guide workforce development. Administration staff should support science leadership.

Flatten the hierarchy – no more than 3 levels from top-to-bottom. The 'Dresden Model' exemplified flat hierarchies as being cost-effective and science-centric (https://www.mpi-cbg.de/about-us/management/our-organization), with directors at the top, then PIs/Services, and lean admin.

Competent leaders must replace 'Yes' People at the Executive level. Yes people i) are not willing to disagree, ii) execute blindly, iii) aren't really listening and disregard the dissatisfaction of their employees, iv) have no idea what's coming next to keep their institute relevant, v) don't take responsibility and divert accountability, vi) kowtow to superiors who, in turn, continue to weed out those whose presence reminds them of their own inadequacies. This leads to dull corporations, largely deserted by enthusiasm, creativity and vibrancy but instead dominated by 'process' and corporate jargon. Unless this changes, most independently thinking and adventurous scientists will leave or remain in hiding. Poorly qualified leadership, giving rise to a propagating chain of science mediocrity, is a hallmark of science corporatization and has the potential to degrade the entire institution. It is only through a meritocracy in which leaders encourage creativity from outstanding subordinates that AgR can expect to meet the many challenges ahead [23].

Focus on the core purpose of science. The purpose of science is to make verifiable discoveries, whether they have a commercial value or not [14]. The primacy of discovery has defined how basic science is organized. First, scientists are measured by the discoveries they make and by their perceived potential to make more of them. This measure ('reputation') holds the components of the system together. Second, the reputation of scientific institutions is measured by their ability to enable discovery by attracting discoverers and continuously providing a supportive environment.

What would happen if the primary purpose of basic research is not discovery, but profit? The system would also look ridiculous and horrifying. What would those who grew up dreaming of becoming great discoverers think, feel, and do? If reputation based on discovery is no longer the currency, then how should funding be allocated? Hence, the search for surrogates to fill the void—the number of papers published, the number of citations, citation indexes, impact factors, formulas to calculate their relative values, and all other administrative inventions to keep the system operating—with the ultimate measure being the money that scientists can bring in [24]. If discovery is no longer the primary purpose, would the people who accept the first convenient finding for the answer have an advantage in securing funding? Would the people who cannot trade their integrity leave science or decide not to come in? If discovery is secondary, is it surprising that the traditional model of operation would change to something different: come up with a nice story, sell it to the reviewers and editors, use the publication as a voucher to get grants to produce more nice stories. If science is a business, why would it matter what is sold? A lost sense of purpose can send a person into a tailspin. The same can happen to an institution.

CRIs represent the worst of both worlds. Neither traditional science nor business, they were made from incompatible parts taken from both bodies with good intentions but not much forethought. Indeed, if CRIs are a business, do they make a profit? If not, why are they still in business? Why are some of its workers engaged in non-commercial research? What does it sell? Why does the CEO keep his/her job if the company makes unreliable products? If it is an institution of basic science, why does it put money before everything else? Why is it involved in selling something? Why has the management assigned itself the role of owners? Why does it have a CEO? Why is it so dull and no longer strives to produce breakthrough discoveries?

CRI hybrids are dysfunctional pseudo-businesses, by analogy to pseudoscience, which is an activity that pretends to be science but does not follow its basic rules.

5. RESEARCH WORKFORCE

Question 14 **"Workforce" is offensive**. The word "workforce" was used by the Russian Communist Party leadership to describe other citizens of the Soviet Union whom they viewed as mere cogs in a machine at the Party's disposal [14]. Indeed, the title of this section could have been composed by an apparatchik, another Soviet term. Despite these connotations, the term "scientific workforce" is increasingly becoming a part of the discourse, not only among scientific editors and administrators, but also among some scientists. Perhaps tellingly, a letter to *Science* from a scientist that discussed the "scientific workforce" was printed next to a letter reporting that "plantation workforce is hired on a daily ad hoc basis" [25]. How could equating scientists to the plantation workforce be expected to benefit science and society? Treating people as a workforce might work in a diamond mine, but not if diamonds are ideas, observations, and discoveries. Why would anyone use such a model? The relationship within the ecosystem changed from one of advisors, trainees, and colleagues to that of a workforce and its users. This change can be explained if we assume the advisors adopted a new behavioural model, likely of corporate origin.

The key question is whether someone who has been treated as cheap labor for a decade of apprenticeship can remain an independently thinking and adventurous scientist. Perhaps those in whom the brilliance of mind is coupled to hardness and resilience of character can make it, if they decide it is worth it. Others drop out or lose their minds. Who, then, will find the cure for cancer?

Inspire excellent scientists. There are recommendations to make science attractive again. As Vannevar Bush, the head of the US Office of Scientific Research and Development during World War II put it so eloquently: "Scientific progress results from the free play of free intellects, working on subjects of their own choice, in the manner dictated by their curiosity for exploration of the unknown…" and noted the complexity of developing scientific talent because "no one can select from the bottom those who will be the leaders at the top because unmeasured and unknown factors enter into scientific, or any, leadership. There are brains and character, strength and health, happiness and spiritual vitality, interest and motivation, and no one knows what else, that must needs enter into this supra-mathematical calculus [16]." This language might be considered fanciful by today's standards, if not for the reputation of the author and the success of his vision.

Question 15 **A base grant would make science a more attractive career choice** than the current competitive funding model where scientists are employed, then soon find they only have a secure job if they are successful in funding it. A base grant should cover salaries, operating costs, and overheads (including key resources such as library services, statisticians, databases etc.).

Base funding would enable research institutions to maintain and improve core functions. Base funding of scientists and their overheads for core functions will enable building of expertise.

Some competitive funding should be maintained to encourage innovation, especially in developing concepts for new research priorities. They provide a way of incorporating new staff (Post Docs and students) into projects to develop and prove themselves.

Question 16 **Stop treating young scientists as cheap labour**. Young scientists are colleagues in exploring 'Science, the endless frontier', not an economical 'workforce' that is mass-produced in the quantities required to satisfy the demand of stakeholders. How can someone who struggles through a succession of short-term post-doctoral positions remain an inspired, passionate, independently thinking, and adventurous scientist?

Empower the next generation of scientists and science technicians. In Europe, ERC grants brought a breath of fresh air to empower young investigators [26]. At the age of 30, top researchers should have their own grants, providing intellectual and financial freedom. Wellcome Trust (UK) Investigator Awards are similar but focus on investigators rather than projects. The focus is on quality of the candidates, rewarding those with the ability to innovate and drive advances in their field of study. They should be able to articulate a compelling long-term vision for their research and demonstrate the talent, track record and originality to achieve it. Researchers should be free to pursue whatever direction they find interesting within the framework of their award Giving young scientists and technicians more leeway and support to establish their own research teams makes NZ more attractive for kiwis coming back.

Close the pay gap and implement pay transparency. There is both a gender and an industry vs academia pay gap. One strategy to close this gap is by implementing pay transparency — when employees know each other's salaries [27]. The pay gap between men and women tends to shrink after workers learn what their colleagues earn. The relationship between academic performance, such as numbers of papers published, and salary also weakened after the transition to pay transparency [27]. Closing the gap would encourage the best and brightest into science careers. NZ scientists are underpaid by international standards, making it difficult to recruit top scientists from overseas and pay commensurate with their expertise. Not closing the gap for scientists while executive salaries are kept at market parity sends the wrong signal.

Enable researchers to perform their own cost–benefit analyses before applying for a grant. The funder should publish accurate success rates in previous calls, and evaluate the average time spent on proposals by applicants.

6. RESEARCH INFRASTRUCTURE

Question 17 **Government needs to maintain national assets**.

There are many opportunities to share science infrastructure and assets across future organisations and this should become standard practice wherever possible. An example of such an asset is the AgResearch outdoor animal containment facility (ACF). This facility is a national asset, the only place that allows the genetic engineering and subsequent testing of large animals under outdoor conditions. It is used for agricultural and biomedical applications by a wide range of national and international stakeholders. Yet the facility is under constant threat because its financial upkeep is solely the responsibility of a single CRI (AgResearch) with limited resources. Such facilities, as well as other research farms, should be nationally funded and maintained.

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