Innovation and Ignorance

How Innovation Funding Cultures Disincentivise Endocrine Disruption Research

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Abstract

Over the past four decades we have witnessed a surge in non-communicable diseases such as cancer, diabetes and neurological diseases and disorders. While non-communicable diseases are primarily caused by non-genetic, environmental factors, environmental health research to explore this phenomenon remains poorly funded. Funding resources in the physical sciences are principally directed towards biomedical research examining genetic and molecular processes, rather than directed towards exploring the role environmental factors play in establishing and promoting the conditions for disease and health disorder.

Endocrine disrupting compounds (EDCs) are chemical pollutants, which contribute to the aetiology of common non-communicable diseases and disorders including cancer and diabetes. EDCs appear particularly harmful to the developing brain, contributing to intelligence (IQ) loss, as well as learning and behavioural disorders. However, EDC research remains under-recognised and unfunded, contributing towards a form of ignorance.

I have identified that research that could draw attention to environmental harms often remains outside the scope of science policy in modern economies. These economies position science as a mechanism to solve human problems via the development of innovative technological solutions. This marginalises the role of scientific research that explores non-genetic factors, including pollution, in the aetiology of disease and disorder.

To understand this phenomenon more clearly, I examine EDC research in New Zealand. This is a particularly strategic case to examine as EDC research in New Zealand is rare. There is no cohort of scientists researching this field. To shed light on this dearth of research this thesis pursues a two-pronged approach. First, I analyse science policy to identify the political, cultural and social norms that frame policy and encourage resourcing of particular forms of science. Second, I interview scientists about the research funding regime in New Zealand.

I found that science policy encourages key logics that favour economic growth, innovation and accord with biomedical cultures and norms. In health research, these processes privilege the funding of biomedical research while displacing research that contradicts these logics, such as EDC research. Hypercompetitive funding environments appear particularly stymied by research that does not align with the dominant logic.

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I acknowledge the kindness of Dr Manuel Vallée in trusting in me to pursue this research project. I am grateful for your substantial patience and persistence, and your insight and your clarity.

To my husband Darren, son William and daughter Rose, you are the sparkle in my day, the wit that keeps me smiling, and the logic that keeps me grounded.

I also acknowledge my father Robin, who took me bush, imprinting ecology into my soul, and who taught me the meaning of love. I am also endlessly indebted to my strong, beautiful, astute and endlessly caring aunts, who in their grace, gave me something to aim for.

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Thesis Overview

This thesis explores the dramatic underinvestment in human health research researching the non-genetic, environmental factors that contribute to the aetiology of disease and disorder. This is important because environmental factors, rather than genetic inheritance, are the major drivers of disease or health. Yet research in the physical sciences that can explore the interaction between environment and human biology remain almost invisible. By contrast, governments contribute billions of dollars to support biomedical research which seeks to identify genetic and molecular pathways that can be targeted towards diagnostics, instrumentation and treatments inside the health sector.

This thesis considers the struggle of physical scientists in obtaining funding to research the human health risk that arises from environmental chemicals that damage hormone function. Healthy hormone function is crucial to human health. Hormones regulate growth and development, sexual characteristics, fertility, and metabolism. The immune and hormone system are deeply integrated and healthy hormone function is particularly important for neurological health.

Synthetic household and industrial chemicals can mimic, disrupt and perturb hormone activity, damage health and contribute to the burden of disease (Grandjean & Bellanger, 2017). These chemicals, known as endocrine disrupting compounds (EDCs). EDC exposures are non-voluntary exposures that interfere with a wide range of biological processes. An increasing range of common conditions, including obesity and metabolic disorders, reproductive disorders and cancers, thyroid disorders, neurodevelopmental disease and IQ loss are associated with hormone, or endocrine disrupting compounds (Demeneix & Slama, 2019; Kumar, et al., 2020). The neurological impact of endocrine disrupting compounds is estimated to be the greatest contributor to the burden of disease from EDCs (Attina et al., 2016). Early life exposures can cause life-time harm (Kassotis et al., 2020).

EDCs are pervasive, invisible pollutants in everyday life. EDCs are found in a wide range of environmental, household, dietary and personal items and substances. Unlike tobacco, endocrine disrupting substances are invisible ingredients in these items that are not easily isolated nor avoided. However, like tobacco, from the earliest naming and discovery of EDCs, EDCs have been politically controversial (Krimsky, 2000).

The implications for toxicological risk assessment are extraordinary. Recognition of chemical harm infers regulation to protect health. EDCs operate far below the levels conventionally considered safe

in risk assessment, and failure to consider the potential for endocrine disrupting properties in chemical risk assessment likely underestimates the potential for harm (Vandenberg, 2019).

The field of EDC research is well established, with expert scientists in agreement regarding the definition of endocrine disruptors, their risk profile, and how to progress with research and regulation (La Merrill et al., 2019; Solecki et al., 2017). EDC researchers work across the social and STEM disciplines, engaging a broad array of scientific methodologies to triangulate data and build risk profiles of synthetic chemicals in order to demonstrate potential endocrinologic activity. Scientists have suggested a suite of testing modalities including high-throughput screening to assess whether chemicals interact with hormone receptors, invitro testing and other forms of mechanistic testing. Secondary research has been recommended to explore in vivo research in vertebrate animals and epidemiological research in human populations. Because of the potential for hormones to interact with biological systems, and for there to be feedback loops and complex cascading effects, scientists emphasise the importance of in vivo studies to analyse biological interplay (Kassotis et al., 2020).

There is no cohort of basic and applied scientists engaged in research investigating the health threat from endocrine disruptors. New Zealand[i] has four brain research institutions yet no scientists are engaged in exploring the potential for endocrine disrupting compounds (EDCs) to adversely impact neurological development, behaviour and intelligence. Neither white papers nor policy documents have been produced in New Zealand. The regulatory sphere has not amended legislation and regulation to account for the hormone-level risk from regulated chemicals.

In contrast, a 20-year body of work can be found with many OECD nations, particularly in Europe. It is as if the knowledge that lies within the dominant global institutions such as the U.S. based National Institutes of Health (Weaver, 2021), the OECD (Holland, 2018) and the European Commission (Demeneix & Slama, 2019; E.C., 2021), has simply not reached the New Zealand. Denmark, with a population of under six million, has undertaken extensive work on the subject (CeHoS, 2021). Science advisory ecosystems rely on scientists to provide knowledge, but New Zealand lacks dedicated scientists that can provide expertise in this matter. Scientists can occupy positions in academia, in research institutes, occupy positions in regulatory and policy agencies and

[i] Throughout this thesis I refer to New Zealand, as opposed to Aotearoa New Zealand. Absent governance of EDCs, the state cannot safeguard the wellbeing of uri whakatipu (future generations) and exercise kaitiakitanga (stewardship). EDC's impact all vertebrates similarly, thus fertility, learning, intelligence etc can also be undermined in, for example, indigenous fish species, birds, and tuna (longfin eel). Deficient hunting and predator escape skills undermine intergenerational resilience.

work in independent think tanks, sit on advisory boards and act as advisors to government (Gluckman 2018). Our public sector is silent on this matter.

As health research funding is highly competitive, approval for funding demonstrates a field is both recognised and prioritised. Science production is a result of political decision-making at the macro-level; the operation of meso-level level institutional environments; and the result of micro-level activities of individual scientists. Gläser & Laudel (2016) have noted that "sociological studies of links between conditions and outcomes of the social construction of scientific knowledge miss an important factor shaping knowledge if the governance of science is excluded from scrutiny" (p. 119).

The production of science is highly social, involving the negotiation of elite groups (Gieryn, 1995; Jasanoff, 2011); peers (Latour & Woolgar, 1986); declarative bodies (Stark, 2014) and social and cultural norms (Travis & Collins, 1991). In science, power and knowledge is a function of historical access to resources, as capital "takes time to accumulate" (Bourdieu, 1986, p. 46) The control or funding of the production of that knowledge and non-knowledge, and the authority to determine which science is legitimately included in debate is tactically important and a function of the power of stakeholders (Croissant, 2014; Hess 2015).

This research project aims to shed light on the barriers to the production of EDC research in New Zealand. This thesis uses a political sociology of science approach that explores the political, economic, cultural and social factors that co-produce funding environments that privilege certain institutional actors while stymying others (Frickel & Moore, 2006). I have undertaken this by examining the interacting dynamics at the macro-level of policy, the meso-level of funding panel culture and norms, and at the micro-level, by exploring scientists' personal experiences in science funding (Gläser & Laudel, 2016, p. 119).

I applied two overlapping approaches to delve into this issue. First, I investigated the changing political climate of science production in New Zealand. My exploration paid particular attention to the political dynamics shaping science policy and the funding process over the past three decades, and the discourse applied within science policy. In exploring discourse, I am referring to the systems of ordering in policy, documents and interviews which brings to light ingrained, well-embedded interpretive schemata that reflect cultural, social and political understandings, and which guide problematising. Secondly, I interviewed a cohort of institutional researchers to understand their experiences in navigating research funding schemes and securing research funding.

My findings reveal that national science (MBIE, 2015) and health research (MBIE & MoH, 2017) policies standardise funding scheme criteria. Normative criteria emphasise investment in health research that is innovative, excellent and that translates into practical, or translational, use in the health sector. This approach is the consequence of three decades of state policies situating investment in scientific knowledge-production as a key driver of innovation and economic-growth.

For physical scientists, the research trajectory that most complements these political priorities, and that is most easily measurable (MBIE, 2018) is biomedical research. Biomedical research aims to discover new biological pathways or mechanisms, the discovery of which will enable translation into innovative processes, diagnostics or treatments. Translation is a biomedical term that infers research outcomes will be translatable into clinical settings. For scientific peers and clinicians on funding panels, the prevailing policy discourse emphasising innovation, translation and excellence appears culturally normative. Historically panel members have been awarded funding that conforms to these norms. However, this confluence of policy and biomedical culture steers physical (basic and applied) scientists towards the development of clinical and biomedical interventions, treatments or drugs for a single disease. The effect of these forces is to explicitly and implicitly downplay and depoliticise the role of the so-called “hard sciences” in drawing attention to the social and environmental drivers of non-communicable disease. Therefore, normative policy discourse generally positions epidemiological and social science research as “public health” research, whilst physical science research is expected to produce a biomedical outcome.

I argue that the structural factors create feedback loops, disabling the development of a cohort of scientists that might progress this field in the public interest. The dominant framing around investment, innovation and translation also leaves little room for funding panels to support ambiguous, complex and potentially controversial research exploring environmental exposures and stressors.

The current situation is exacerbated by two dilemmas. First, the absence of structural mechanisms such as an institute, expert scientific peers and authoritative experts with sufficient political authority that might advocate for non-biomedical, or EDC research. Second, only a minority of proposals are funded. The common practice of having to discount normal, good quality science in hypercompetitive funding environments increases the tendency that conservative, orthodox science conforming to normative scientific paradigms will be selected above non-normative, unfamiliar proposals.

Public health necessarily involves shifting the gaze upstream to the drivers of disease that are more likely to be socially rather than genetically determined (Karlsson, et al., 2020; Wild, 2005). The global non-communicable disease epidemic is primarily social in origin (Baker, et al., 2018; WHO CSDH, 2008) and health trends in New Zealand reflect international trends. Our poorest and most marginalised are our most unwell (MoH, 2018). Despite this knowledge, political actors have long failed to sufficiently prioritise research examining the environmental and non-genetic drivers of disease (Baker, et al., 2018).

Chapter One explores the scientific and social science literature to outline the human health risk of EDCs across a broad spectrum of biological pathways. Environmental drivers of disease continue to receive low priority for public research funding, even as research technologies are available. New Zealand has local institutions that could be engaging in this research, but are not; and stewardship of EDC contaminants remain decades behind other OECD countries.

Chapter Two describes the methodology, outlining the research design and the rationale for the design. I also discuss how this research expands upon existing research, the issues I had with obtaining the data and why this research is strategic to use.

Chapter Three briefly examines literature concerning the social, political and economic forces that shape the production of science. This literature is drawn from sociology, science, management, and public policy and behavioural studies. This chapter starts by outlining patterns of structural and policy shifts that have occurred over a thirty-year period. These shifts include increased state oversight of science production; the rise of externally sourced resourcing via contestable funding schemes; increased research evaluation and accountability processes; and greater emphasis on the economic value of research knowledge. This chapter then reviews the literature exploring how scientists have adapted to altered funding environments, and scientists' experiences. Particular attention is paid to the influence of hypercompetitive funding environments, disciplinary conservatism and the difficulty in undertaking scientific research that is innovative, unorthodox and outside policy objectives.

Chapter Four firstly discusses institutional and cultural shifts across the academic, public health and science communities that embedded market norms of competition, accountability, and economic growth across public sector life in New Zealand. These communities propose and distribute grant funding for health research. Additionally, the chapter explains that this shift has been shaped by the emergence of a discourse that emphasises innovation, excellence and translation, and the absence of discourse that provides a place for public good science to inform policy.

Chapter Five reviews the historic trajectory of public health. Public health has shifted from a primary focus on infectious disease to recognise many non-genetic drivers of disease. However, as the burden of non-communicable disease (NCD) has grown, research funding in the physical sciences has not developed commensurately to address the non-genetic drivers of disease. This chapter draws attention to the shifting of public health to emphasise biomedical and behavioural processes which emphasise translation inside the health sector. It focuses on the fact that lower-socioeconomic groups are disproportionately at risk from public health threats, including multimorbid health conditions. I discuss the biomedical origins of translation and how this aligns with state policy, shaping health research towards innovative, biomedical outcomes. I contend that this narrative displaces and deprioritises research exploring pollution, racism and poverty as dominant drivers of disease.

Chapter Six identifies key terms and associated logics that shape a matrix of decision-making for funding panels. These overlapping factors act as controlling processes (Nader, 1997) to frame decision-making, perpetuating biomedical logics and stymying research proposals outside funding panel frames. These observations have been drawn from interviews with New Zealand and Australian health researchers in securing and maintaining research funding. I identified disparate logics between funding panel members operating within a biomedical framework, and physical scientists researching outside the biomedical framework. Highly competitive environments amplified risk for both funding panels and physical scientists, and increased the likelihood non-biomedical, unorthodox or ambiguous science would be downgraded.

Part I. Invisible, Crescive Harm.

Chapter 1. Endocrine Disruption

1. INTRODUCTION

Manmade environmental stressors are increasing rather than decreasing. In the last two centuries, chemical production has accelerated profoundly, and the most remote regions now carry a chemical signature, either from local emissions, or via exposures transmitted along air and water currents (Colborn et al. 1997; Scheringer, et al., 2012) Chemical residues contribute to the sedimentary layer now classified as the post-industrial Anthropocene (Crutzen, 2002). The modern era has witnessed unprecedented expansion in chemistry and technologies that through use, leave residues behind. The global chemical industry was valued at USD$5 trillion in 2017. This is projected to double by 2030. While there are 40-60,000 chemicals in commerce, approximately 6,000 chemicals account for ninety-nine percent of the total volume. Over 60% of the total volume of chemicals are recognised as hazardous to health (UNEP, 2019, p. 3).

The knowledge gaps regarding chemical toxicity are extraordinary. Only a small fraction of chemicals has been tested to identify their potential to disrupt hormone systems (WHO UNEP, 2012). Many chemicals evade regulation, formulation mixtures frequently remain undeclared, while commercial in confidence agreements form an ongoing deterrent to transparency in regulatory approvals (Gabb & Blake, 2016; Mesnage et al. 2019).

This chapter firstly discusses the extent to which EDCs pose a health risk, and the importance of prioritising research in order to protect human health. Public health research can act as a counterbalance to industry power. Secondly, I discuss the institutional absence of EDC-related research in New Zealand.

2. BACKGROUND: ENDOCRINE DISRUPTING CHEMICALS

EXPOSURES TRESPASS TIME AND SPACE

The link between endocrine disrupting compounds (EDCs) and a wide range of non-communicable diseases and disorders grows daily more compelling. A large body of evidence suggests that many chemicals claimed as safe by regulatory agencies and corporations, are not safe. Scientists consider that endocrine disrupting chemicals (EDCs) can be regarded as another determinant of disease, alongside smoking or alcohol (Grandjean & Bellanger, 2017).

The implications for learning, behaviour and intelligence and life quality are particularly concerning. Scientists consider the greatest societal cost of arises from impaired brain function, reducing intelligence and impacting cognitive function, including behaviour (Attina, et al., 2016; Demeneix & Slama, 2019). Brain health or impairment is related to socioeconomic status and potential for wellbeing over the life course.

There is no such thing as a safe level of EDC exposure. Scientists view the risk from EDCs similarly to risk from carcinogens and mutagenic substances. The degree of potential risk differs with life stage. Pre-conception exposures can damage subsequent generations; and exposures during vulnerable developmental stages can have different effects depending on the developmental stage in-utero, in infancy and throughout childhood and adolescence. In many instances, the resultant harms may not be visible for decades and generations (Attina et al., 2016; Boudia et al., 2018; Demeneix & Slama, 2019; Kassotis et al., 2020; Krimsky 2014). Exposures in pregnancy, and during vulnerable developmental stages are particularly risky (Krimsky, 2014). Because of inestimable individual vulnerability, precise thresholds cannot be derived, yet the harm that occurs from exposure in vulnerable developmental periods appear to place global populations at greatest risk (Demeneix & Slama, 2019; Grandjean & Bellanger, 2017; Gaudillière, 2014). Vulnerable groups can be protected through regulation, as the regulatory status of a chemical directly effects population exposure levels (Kassotis, et al., 2020).

Exposure scenarios can be mindbogglingly complex. While conventional biomedical and risk approaches consider the impact on a single pathway, EDC researchers frequently explore multiple pathways. For example, Bisphenol A (BPA) is associated with a broad spectrum of health impacts which include cancer, fertility, neurological, and immunological problems (Robertson & Farrelly, 2015). However, BPA is one member of the bisphenol class. A single class of chemicals, such as the bisphenol or PFAS (per-and poly-fluoroalkyl substances) class can contaminate a broad range of household products, and in doing so, disrupt multiple biological pathways (Encarnação et al. 2019). The complexity does not end there. Multiple chemicals can act additively to interfere with the regulation of a single hormone, such as when natural oestrogens in soy accumulate with synthetic chemicals that contain oestrogenic properties. Inevitably there is a cocktail effect. Combinatory mixtures can act additively and synergistically to disrupt or block impacting multiple hormonally dependent pathways simultaneously, such as through ingredients in processed food and food packaging (Demeneix & Slama, 2019; Krimsky, 2014). Finally, the microbiome is an important unexplored avenue for EDC research and there are direct associations between neurological health, immunity and EDCs (Kumar, et al., 2020)

POLITICAL, AND THEREFORE CONTROVERSIAL

EDCs once identified, were immediately political. Proctor has written of the "politics of dose response curves" from chemicals that harm at doses normally considered safe (Proctor 1995). These chemicals are invisible and ubiquitous. They are ingredients in food, drink, air, cleaning agents, and household and personal care items. More than one thousand chemicals have been identified as endocrine disruptors (Schug, et al., 2016) and more than 20,000 scientific peer- reviewed articles have been published on endocrine disruption (Lamoureaux, 2019).

Science which creates economic, political, and social dilemmas can be difficult to obtain resourcing for (Oreskes & Conway, 2010; Proctor 1995; Rayner, 2012). Sheldon Krimsky was one of the first social scientists to explore the experiences of scientists in attempting to bring EDCs and their risk to vertebrates (including humans) onto public policy agendas (Krimsky, 2000). Krimsky identified the social and political response to the release of the book Our Stolen Future (Colborn 1997) through an analysis of newspaper op-eds and book reviews in the scientific literature. Krimsky identified themes which shape institutional response to EDCs - the conservative ethos within science, the tensions between science and policy, the role of regulatory, industry and advocacy groups in public debate.

Scientific research is being undertaken at an international level by cohorts of scientists working across disciplinary fields (Attina et al., 2016; Encarnação et al. 2019; Honkela et al. 2014; La Merrill et al. 2019). This research involves a great deal of uncertainty and indeterminacy due to the variability of the human exposome, the "cumulative lifetime environmental exposure and related biological responses" (Karlsson et al., 2020). This research can be professionally risky as it involves estimating health in scientifically unconventional ways. Yet there is scientific consensus as to how to progress research (Kassotis, et al., 2020; La Merrill, et al., 2019).

EDCs show similarities to other unavoidable health harms that governments are expected to regulate or manage. Exposures are commonly non-voluntary. Unwanted chemical exposures and disease risk show striking similarities to other socially determined health harms, which include poverty, tobacco and processed food (Grandjean & Bellanger, 2017; WHO CSDH, 2008).

As with the other social determinants of health, scientific research in this field has the potential to produce "uncomfortable knowledge". Uncomfortable knowledge is knowledge which, if produced is likely to conflict with organisational principles and goals. This form of scientific knowledge can be suppressed or simply remain unfunded and undone (Rayner, 2012). When chemicals are demonstrated to be harmful, and regulated they are often heavily restricted or withdrawn from

production. Implications for industry include the cost of redesign and production, the risk of litigation, costs of product stewardship or public acrimony. Organisations have a range of strategies that are engaged to ensure that regulatory inaction is sustained, and doubt is maintained in order to prevent regulatory action (Michaels, 2020; Oreskes & Conway, 2010; Proctor 1995). When scientists start to build a body of evidence around the toxicity of a product, it is rare for industry science to overturn it (Michaels, 2020). Yet paradoxically, the more science knows, the more science doesn't know. Ignorance and non-knowledge will always be present. With each tested hypothesis, more questions arise, and the uncertainties broaden (Krimsky, 2014).

Sociologists have envisaged EDC research as a new scientific paradigm. Christenson and Casper (2000) reviewed both sites of power and agency, government, industry and policy, and activism and breast cancer risk. They also drew attention to the social nature of exposure, the sites of vulnerability, the invisible farmworker, and the foetus, asked that social scientists consider the social worlds impacted by hormone disrupting substances. Casper (2003) subsequently urged that researchers "follow the molecule" and incorporate not only the site of production, but the political institutions which perpetuate and legitimate chemical exposures. More recently sociologists have envisaged a future vision of EDC intergenerational justice that encompasses a politics of difference (Lee & Mykituik, 2018) and explored the qualities of chemical residues. EDCs have directly social, political and material qualities. Soraya Boudia et al. (2018) have outlined how chemical residues are not merely unbounded, invisible, slippery, and persistent, their effects can be non-linear. Exposure can result in greater effects at hormone levels than at higher thresholds declared safe. Residues accumulate as outcomes of human activities. Once identified, they are expensive to clean up, and can create cascading effects that imply responsibility, and so the identification of residues is contested by the agents involved with release and regulation.

INTERGENERATIONAL IMPLICATIONS OF EPIGENETICS

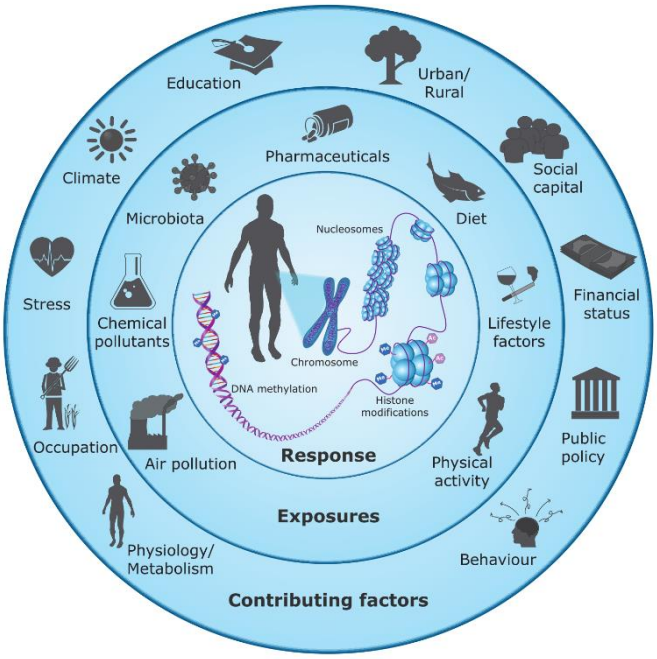
EDCs can alter hormone function intergenerationally through epigenetic processes, without changing DNA (Demeneix 2019). Epigenetic regulation is an integral component of biological function, our gene expression is constantly modified through the actions of internal (endogenous) biological processes and external influences, such as nutrition, stress, and chemical exposures. Epigenetic modifications are changing how scientists view heritability and environmental vulnerability. EDCs are a subset of a suite of environmental stressors that can alter gene function (Norouzitallab et al. 2019). Scientists have observed transgenerational effects resulting from EDC exposure to the germ cells, reproductive organs and brain (Rissman & Adli, 2014). The role of

environmental causes in shaping intergenerational health shifts attention further away from genetic determinacy and closer to socioeconomic and material capabilities (Landecker & Panofsky, 2013).

3. GOVERNANCE AND RESEARCH GAPS

THE EXPOSOME

The term *exposome* was coined by Chris Wild to explain the non-genetic factors that promote disease. Wild had observed an asymmetry in cancer research trajectories, with cancer research prioritising the identification of genetic and molecular pathways for treatment over research aimed at identifying the environmental drivers of disease (Wild, 2005; Wild, 2012). The exposome, or total of an individuals' exposures, are differently reflected by income, climate change, culture, geography and diet (Norouzitallab et al. 2019).



Karlsson et al 2020. The Human Exposome & Health in the Anthropocene. *Int J Epidemiol.*

RESEARCH FOCUS: GENETIC AND MOLECULAR PROCESSES

The Human Genome Project triumphed in mapping the human genome, however the resultant data revealed that genetic heredity formed a much minor role in the production of health and disease than previously thought. Research presently indicates that seventy to ninety percent of disease risks are due to differences in environments (Rappaport & Smith, 2010).

Research exploring the environmental drivers of disease remains low priority for research funding. Despite the exponential expansion in genetic knowledge, such as through genome-wide association studies (GWAS), "enrolment in studies of nongenetic environmental exposures remains relatively low" (Vermeulen et al. 2020, p. 3). GWAS advances provide an opportunity to explore environmental exposures. While technical capability has increased, however, environmental research continues to lag behind genetic and molecular research. Ongoing GWAS research supports the fact that genes play a small part of disease aetiology (Jones, 2016; Rappaport, 2016). Rappaport (2018) suggests that "the modest effects of heritable genetics suggest that exposures and/or gene–environment interactions are major causal factors" (p. 1) and continues "[in] the age of GWAS it is

difficult to reconcile the crude state of knowledge about environmental exposures that has been gleaned from traditional methods" (p. 4).

Technological advances carry with them incredible potential. Large exposure related risk studies can mimic earlier gene-disease association studies to study the development of the diseases increasing in prevalence (Jones, 2016). High-resolution exposomics enable researchers to hypothesise about causal exposures and biological pathways "[U]sing high resolution mass spectrometry linked to a chromatographic separation technique, it is possible to measure tens of thousands of chemical signatures from the same sample, representing both endogenous metabolites and exogenous exposures" (Burkett & Miller, 2021, p. 263).

Metabolomic profiling can extend beyond endogenous molecules, to screen for exogenous molecules including nutrients and chemical contaminants (Barouki et al. 2018).

Finally, the scientific community are keenly aware that exogenous chemicals alter endocrine function and bio-chemical interplay is conventionally accepted in medicine. Nutrient levels correspond to healthy hormone levels. Biomedical research explores the interaction of endogenous chemical processes and gene expression to identify hormone level treatments. Whilst considerable uncertainty about the processes, pathways and endpoints exists, this science is funded and is not politically controversial. Uncertainty has not prevented this science from being undertaken. This is discussed further in Chapter 6.

STEWARDSHIP IN NEW ZEALAND

New Zealand lacks an institution with financial flexibility to undertake exploratory, diagnostic research in the physical sciences to research human health harms in New Zealand. This work can complement epidemiological and social science research. This work helps inform democratic debate and can guide governing and regulatory bodies. It is largely exploratory and often multidisciplinary. This research produces indirect and difficult to assess economic benefit. This form of research draws attention to the externalities of industrial production. Horne has suggested a market failures approach to public health ethics where "the role of public health is to correct public health-related market failures where possible, not merely to provide health-related pure public goods" (Horne, 2019, p. 290).

As with tobacco, this work is political. However, scientists and decision-makers can move forward when factors are both political and sociobiologically complex, as happened with tobacco regulation (Bradford Hill, 1965/2015). The state intervenes as tobacco manufacturers will not pay the cost of

consequent diseases, there are consequent spillover effects, or externalities that produce a cost to society. Externalities are costs or benefits to third parties that are not reflected in the price of a good. Action on tobacco corrects a public health-related market failure.

Information in Aotearoa New Zealand involving the potential for endocrine disrupting substances to cause health harm is negligible or weak at best, and poorly represented throughout academic scholarship, governance and media (Robertson & Farrelly, 2015). Local journals do not appear to focus on health risk from endocrine disruptors. Searches backdated ten years in the Australian and New Zealand Journal of Public Health could not identify content including the term endocrine disrupting/ion; while a search in the New Zealand Medical Journal mentioned endocrine disrupting/ion twice (Carran & Shaw, 2012; Penny & Carryer, 2011).

New Zealand courts have not experienced high profile cases that draw attention to low doses of hormone mimicking chemicals and their potential to contribute to disease, as has happened in other jurisdictions (GCEU, 2015). Similarly, media has shown little interest in discussing the potential for EDCs to harm health (Robertson & Farrelly, 2015) despite the increase in many hormonally mediated diseases (MoH, 2018).

The Research Centre for Hauora and Health (RCHH, formerly the Centre for Public Health Research) focusses predominantly on epidemiological, biological monitoring and social science research. The centre is investigator-initiated and externally funded through contestable funding schemes. The RCHH maintains research laboratories to process and analyse biological samples. Researchers collaborate broadly across the New Zealand landscape. While work has been undertaken to explore the presence of environmental pollutants that are EDCs, the RCHH has no scientist cohort researching EDCs.

The Institute of Environmental Science and Research Limited (ESR), researches infectious agents and human health, but has no history of researching human health risk following sub-lethal chemical exposures. ESR receives project-based funding through the Ministry of Health. While engaged to produce health risk reports, ESR rarely alludes to EDC properties of reviewed substances (ESR, 2020a) ESR's purpose is to "support the health, economic, environmental and social wellbeing" (ESR, 2020b, p. 5). The screening (testing) of synthetic chemicals, or "emerging organic contaminants" in water and waste are one element of ESRs work programme. ESR do not currently screen human samples and ESR's human health role is limited to drinking water safety and infectious disease research, including "antimicrobial resistance, influenza, vaccine preventable diseases and gastroenteritis" (ESR, 2020b, p. 25).. New Zealand's most resourced public

laboratories, AsureQuality and the ESR laboratories operate as privatised models and the human health effects of environmental chemicals appear to be outside the present funding scope.

Where there is absence of social movements to counteract industry-regulator relationships regulatory policy tends to follow in the direction established by industry (Michaels, 2020). New Zealand has no formal policy or guidelines concerning the human health effects of EDCs. Regulatory institutions have been criticised for failing to new knowledges into account (Iorns Magallanes, 2018; Vandenberg, 2019). The European Commission released its first EDC legislation in 1999, and since this date over EU150 million in funding has been directed to research on EDCs. The United States National Institute of Environmental Health Sciences has been carrying out research for over three decades (NIEHS, 2020). With the exception of one internal report to the EPA Board in 2017, the NZEPA has not authored documents nor provided policy advice concerning the risk of EDCs to the New Zealand population.

4. CONCLUSION

Public institutions have a defining role in legitimating what science is accepted as normative in the public sphere. The third duty of government, beyond supplying a judiciary and a military, is in the maintenance of public institutions or public works for which the market would not ordinarily supply (Michaels, 2020; Smith, 1776). This strengthens the economic enterprise to restrict or prevent market failure. As Michaels (2020) has observed, “law and regulation are the underpinnings of the free market system (…) the state fosters a safe space for market growth” (p. 271).

Chapter 2. Methodology

1. INTRODUCTION

This thesis seeks to understand why there is no research being pursued in New Zealand to understand the risk of endocrine disrupting compounds to human health. This research gap is of particular interest as New Zealand has a substantial health burden, many of our prevalent conditions are associated with EDC disruption. In researching this issue, I sought to identify the structural (cultural, economic and political) factors that might prevent this research.

2. RESEARCH DESIGN

To shed light on these issues I sought to better understand how the research has been mediated by research funding environments. Research funding is an important issue. As scientific research is frequently an expensive undertaking, financial support is required.

To better understand how research is mediated by funding, I pursued a qualitative research design that combined interviews with key informants and discourse analysis of key policy documents.

Key informants were New Zealand and Australian researchers and scientists, whom I interviewed regarding funding issues pertinent to EDC research. Scientists are particularly important in this regard as they must prepare and present funding proposals to peer review funding, or grants panels. These panels then evaluate the research for funding suitability. As funding is highly competitive if the funding proposal is regarded as not of sufficient quality, too risky and uncertain, or not sufficiently novel, it will be downgraded and unlikely to be funded.

As very few New Zealand scientists actively research endocrine disrupting compounds and human health, and the research project was expanded to include Australia in order to ensure anonymity for New Zealand participants. While most of the Australian scientists were working in dedicated laboratories, they were still able to identify the challenges of EDC research, and in particular, the cultures and norms of funding environments. This enabled me to establish normative funding challenges for EDC researchers which, due to the small cohort in New Zealand might not be able to have been established.

My inclusion criteria was that participants had to have a research background in human health, and that their research background had focussed on, or presently focussed on a health condition whose aetiology of the disease or disorder was associated with changes in hormone functioning. As these

parameters demanded substantial professional expertise, all participants identified correspondingly had a medical degree, were working at post-PhD level or both.

Many endocrinologists worked in disciplinary areas where scientific studies had identified EDCs as a risk factor in the aetiology of their disciplinary field of expertise, yet their work did not traverse into EDC research. They were also included in my search.

Firstly, permission to research was secured from the Auckland Human Participants Ethics Committee (Reference Number 024553).

In order to identify participants, I adopted a three-pronged approach. First, I contacted the Health Research Council (HRC) to confirm that no grants had been approved for EDC research projects. The HRC is the major health research funding body in New Zealand. The HRC confirmed that no researchers had received funding through the dominant health research institute to directly explore the impact of EDCs the preceding ten years. Contacting the HRC also helped me identify scientists who might be suitable participants as it supplied me with a list of grants that had been funded in the more general area of endocrinology. Second, I conducted searches on university databases in Australia and New Zealand for endocrine and endocrine disruption to identify researchers in human health that fulfilled the described criteria. Thirdly the interview process resulted in a small number of scientists being recommended for inclusion in the project. Purposive sampling was finally undertaken through searches of the National Science Challenge, a diabetes website and Centres of Research Excellence websites which enabled me to cross reference potential participants.

Fifteen Australian and New Zealand scientists joined as participants. I then undertook semi-structured one-on-one interviews over Zoom with Australian and New Zealand scientists. My impression was that the Zoom interview process was collegial and convenient for the participants, with only one scientist having problems with sound.

Permission was sought from the participants to record the interview and the participants were again advised that the interview would be transcribed by the interviewer, and that no third party would be involved with transcription. Interviews ranged from 30 minutes to 70 minutes. The interviews sought to establish the participant’s experience, knowledges relating to endocrine disrupting chemicals as well as their perspectives on the challenges and opportunities for researching the human health risk of exposure to EDCs.

As participants were working at post PhD and/or had previously acquired a medical degree, participants exhibited a high degree of comprehension and autonomy were able to address questions

in considerable depth. 14 of the 14 participants were working at post-PhD level. With the exception of 2 clinicians, all participants worked as basic scientists, clinical researchers or epidemiologists. All participants had laboratory-based or epidemiological research experience and had published articles in their field of expertise. 6 participants were female. Attention was paid to inviting individuals of Māori, Pasifika and ethnic minority descent as these communities can be of lower socioeconomic status, have disproportionately worse health outcomes and reside in environments where they are more vulnerable to environmental pollution. However, very few researchers could be identified in these groups and only one participant was non-white.

10 participants, and all those with expertise in EDC research were either professors or associate professors. It can be assumed that these actors have a track record producing high quality science. Their experience in being rejected for funding is then not likely to be because the science they are seeking resourcing for is of lesser quality than funding proposals that are granted. In addition, because these scientists were operating at a high level, many had served on funding committees, could associate funding patterns with higher level governance imperatives and were comfortable conversationally transitioning from a macro to a micro level.

Following interviews, I categorised participant expertise in human health research and EDCs into four groups: *considerable, some, none* or *aligned*. Four participants were directly involved in human health research into EDCs, these were categorised as having *considerable* expertise. Three participants with minor experience, such as having undertaken an EDC research project, were categorised as having *some* expertise. Four participants were researching or working in health fields where EDCs are implicated in the development of the organ, disease or disorder they research, but had not researched EDCs. These four were categorised as having *no expertise*. Finally, four participants work in aligned fields, (such as, exploring the effects of toxic chemicals and health risk, or challenging normative biomedical patterns of enquiry relating to human health) were categorised as *aligned* expertise. In this way differing perspectives could offer insight into the challenges, contradictions, and normative conditions of science resourcing and how this might confound or reflect challenges of EDC research.

A gradient in EDC related knowledge in this subject served multiple purposes. First, scientists with *some, aligned or no* expertise in EDC research provided an effective counterbalance to EDC expert scientists. Their inclusion helped me assess the degree to which the general scientific community considered EDC risk and research as legitimate research field in New Zealand, and therefore a valid field deserved of funding. Second, these scientists identified common threads across human health

research environments that resulted in a failure of projects being funded which deepened my insight into what projects were considered fundable in New Zealand.

With allowance for the relatively small sample size of 15, an early and surprising finding was that scientists engaged in research in EDCs were more likely to be educated in broader biological sciences rather than having classic medical training. This was a significant epistemological factor in shaping participant interviews, the work of basic scientific research tends to consider the interplay of broader biological systems. Basic scientists identified the difficulty of researching in a funding system that incentivised tangible outputs and short term funding cycles. Basic scientists were more likely to respond to the invitation to participate than clinical endocrinologists who commonly work within expert disciplinary fields. The epistemological underpinning of a broader basic science approach may have influenced participants approaches to the plausibility of EDCs as a systemic risk, as basic scientists work concerns broader biological function.

In contestable funding environments, the ability of funding panels to identify whether a proposed project is worthwhile for funding is a product of policy frameworks and social and cultural perspectives. Many scientists had participated on funding panels, understand the social and political process, and could articulate issues that contributed to proposals being approved or denied.

In order to inform myself of the surrounding policy and funding frameworks that guide decision-making in the funding environment I conducted a problem-driven approach to analyse science policy discourse in the New Zealand policy literature. Following Howarth and Griggs (2012), a problem-driven approach to discourse analysis involves first, the problematisation of a particular phenomenon, in this case, why is there no funding of EDC research. Second, exploration of underpinning logics, rather than laws or causal mechanisms, governing policy practice, and the conditions that make the policies effective governing instruments was then undertaken. Logics are the systems of cultural elements, such as values, beliefs and normative expectations through which institutions and individuals make sense of and navigate everyday activities (Haveman & Gualtieri, 2017). Third, the elements were synthesised, stressing importance of judgement, and as Howarth and Griggs advised, the "ultimate 'proof' consists in the production of narratives explaining problematized phenomena, which in turn depends partly on the relevant community of critical scholars (p. 335).

I identified the National Statement of Science Investment (MBIE, 2015) and the New Zealand Health Research Strategy (NZHRS) (MBIE & MoH, 2017) policy papers as particularly important

as they contained discourse that had been emphasised in both local and international literature as emphasising neoliberal themes stressing investment, accountability and innovation.

Scientists can identify factors that were recognised barriers to funding of research. These could be correlated with the policy discourse that placed EDC research outside schemes for funding. The flexible research design enabled me to respond reflexively, pragmatically and strategically (Grossberg et al. 1992) to the accumulation of knowledges as this project progressed. For example, in the subsequent interviews I observed repeated use of the term “translation” and “biomedical” and an emphasis on a tangible outcome. I then reviewed the literature to understand the aetiology of translation and biomedical, and observed that they complemented neoliberal norms stressing investment, accountability, and innovation.

In addition, I needed to verify that the public sector in New Zealand was not informed on the subject of EDCs, and that scientists could not rely on institutional support for research projects. First, I conducted key-word searches on the public databases of the public institutions most likely to be producing policy relevant to EDC research or engaging in EDC research. This included Universities of Auckland, Otago, Waikato; Victoria and Massey University; ESR, the New Zealand Environmental Protection Authority (NZEPA) and the Research Centre for Hauora and Health (RCHH - formerly the Centre for Public Health Research). Second, I made Official Information Act requests with through the Ministry of Health and the NZEPA in order to ascertain the degree of expertise and research that had been undertaken in these public sector institutions. Other than one policy briefing by a scientist in the NZEPA, no policy or sustained research concerning EDCs and human health could be identified. This assisted me to assert that that New Zealand was silent on the matter of EDCs.

I then thematically coded the transcripts. A small number of research questions were coded qualitatively, for example, to group educational qualifications, whether exposure from EDCs constituted a plausible health risk, and whether EDCs were normatively considered a problem in academic/university environments. I then coded the balance of data deductively following themes identified a priori in the sociological literature and in the NZHRS. Participant discourse was encoded inductively to identify repetition of themes or patterns. Themes raised by the scientists were included in analysis. A final stage of deduction involved moving back through the data to consolidate dominant themes and logics.

3. RATIONALE FOR RESEARCH DESIGN

Interviews are a good approach for answering my research question because the construction of macro-level policy goals and the framing of schemes shape the "fundability" of science at the micro-level. Scientists could identify the factors underpinning the approval or denial of research funding, acknowledging, as Gläser & Laudel (2016) contend, that "we know very little about those who lose in competitions for grant funding" and "thematic priorities and decision-making practices of funding councils do have an impact. Both the selection processes and their anticipation by researchers result in the latter orienting their research more towards mainstream, low risk, and applied topics" (p. 125).

Policy discourse directly frames how health research is prioritised and directed in New Zealand. While academic researchers are customarily perceived as autonomous, policy can be used to steer research towards areas prioritised by institutions, with the consequence that specific populations are rendered 'more compliant and governable' (Newton, Farrelly, & Sinner, 2020, p. 1; Dryzek J. S., 2013). By undertaking discourse analysis of policy and in scientist participants I aim to identify the "grounding assumptions within these problem representations, genealogies of the identified problem representations, and reflections on silences and effects, always with an eye to contestation and debate around the interventions and how they represent the 'problem'" (Bacchi, 2016, p. 11).

Carol Bacchi and Goodwin (2016) have drawn from Foucault's preoccupation with the practices that construct regimes of truth, and the meaning-making implicit across and within these discursive practices. From this perspective policy is theorised as a form of discourse and discursive practices "comprise the multifarious practices and relations involved in producing 'knowledge' and "what is said" (p. 37). This research process aims to highlight framing and problematisation, and "the way in which policy ensembles, or collections of related policies, exercise power through a production of 'truth' and 'knowledge'" (Ball 1993, p. 14; Bacchi & Goodwin, 2016).

The production of the NZHRS policy has tangible effects (outcomes) for scientists and governing bodies as it creates boundaries for decision-making around what science is and is not recognised as appropriate for funding in New Zealand, and where EDC research sits in this space. As consequent lower-level policy must be consistent with the content in the NZHRS, the NZHRS can be taken to as the primary directive.

4. DATA

The scientists with considerable expertise in EDC research had experienced difficulty in getting research funded and were confident discussing potential barriers. However, not all scientists had experience in EDC research and so there was opportunity for multiple perspectives regarding the space and validity of EDC research in New Zealand. Participant interviews identified themes and variables that made funding of EDC health research challenging. Slightly different cultural and disciplinary perspectives were able to be identified. For example, female scientists tended to elaborate more on the social justice implication of their work, and the importance of science research that explored gender differences in endocrinology. Many of the scientists had participated on funding panels and could comment on the processes of deliberation and the scope of decision-making.

I consider that the experiences of the scientists corroborated with a great deal of social science and science literature which emphasised the precariousness of contestable funding environments. Scientist's experiences similarly reflected a great deal of social science research exploring the impact of neoliberal, biomedical and output oriented funding environments that stress the importance of innovation and applied research. In addition, the themes identified in the governing policies reiterated much of this broader knowledge. Therefore, I consider that the data that has arisen from these interviews elaborates and expands upon existing research. I envisage that the combination of identified published literature, the themes identified in the policy literature and the data arising out of the interviews enables this research to be triangulated as evidence to inform judgements (Brannen, 2005, p. 12).

ISSUES OBTAINING DATA

I acknowledge that qualitative research is necessarily subjective and that this project has been driven by my own interest in this research gap. Due to the breadth of this topic, it is unlikely I have revealed all reasons why this research may not be taking place, nor accurately emphasised the factors considered by individual scientists to be associated with non-funding. Interview responses may at times have been ambiguous, and while attempting to clarify ambiguities, I have accepted that they may have reflected the greater complexities of the situation at hand (Brinkmann & Kvale, 2019, p. 4).

In addition, I could not secure scientists with experience in all fields associated with EDC. I invited experts in the fields of fertility, the developmental origins of disease and paediatrics; brain research; obesity and diabetes; multimorbidity; and hormonally mediated cancers. These fields are all

strongly associated with endocrine disruption from hormonally relevant exposures of EDCs. While I did emphasise it was not necessary that the participant had direct expertise in EDC research, I did not succeed in securing researchers in paediatrics or cancer research, and therefore scientists in these fields remained unrepresented.

RELEVANCE OF DATA

This form of analysis is important as it aims to outline a pattern of association between higher level governance and institutional mechanisms, including policy and the capacity of scientists to undertake particular forms of research. Gläser and Laudel (2016) have stressed the usefulness of such research and that little is known about the impact of governance on knowledge content. The authors stress that whilst inevitably indeterminant, threading together the impact of macro-level structural and policy shifts, the function of governing bodies and the micro-level functions of scientists can help draw attention dually to the production of excellent science and the perpetuation of undone science. This analysis seeks to shed some light on the experiences of scientists aiming to work in an emerging field of science that is internationally recognised as important by international associations yet remains unrecognised and unprioritized by public sector institutions in New Zealand.

EDCs have been identified as a human health threat, and Howard (2011) depicts EDCs as under-recognised and vulnerable to being ignored by institutional interests due to their potential to undermine economic activities. Yet, as Michaels (2020) has discussed, how governance shapes research content is important if we are not only to develop new technologies, but control and protect human and environmental health from the exigencies of existing technologies. The capacity for politically powerful institutions to shape the orientation of state funding is well recognised. Social science drawing attention to the causal web between policy construction and research agendas, particularly in politically delicate arenas, can help with the stewardship of polluting technologies, if we are to safely steward human bodies and earth systems for the benefit of future generations.

Part II. Science as Economic Engine

Chapter 3. Literature Review

1. INTRODUCTION

This project is focused on illuminating the factors that mediate funding access for environmental health research. Environmental or exposome research substantially lags behind biomedical research exploring genetic and molecular biological pathways. This chapter, reviews the literature to outline shifts in policy, governance and funding have reduced the autonomy of scientists, encouraged science aligned with state goals that emphasise outcome-applied discovery

On this topic, the previous literature has illuminated numerous themes that provide structure for this review. First, the replacement of block funding with tightly contested "hypercompetitive" funding schemes which increase the potential for funding to be rejected; second, the increasing influence of state goals directing research to align with economic goals; third, the impact of sociocultural peer review environments in approving funding; and finally, the focus on the potential for the outcome to be of commercial value. These shifts have created barriers to knowledge that can only be obtained through curiousity-driven, long-term, flexible research. Environmental research exploring health harms is necessarily this form of research.

Sociological enquiry exploring the direct experiences of physical scientists negotiating modern funding environments has been most extensively reviewed by Whitley (2010) and Gläser and Laudel (2016) and colleagues, and I acknowledge this cohort's body of research. Their identification of the four themes most clearly enables me to illuminate the factors that mediate funding access for environmental health research.

This literature review has shed light on two knowledge gaps that could contribute to understanding of this dilemma. Firstly, I have not been able to identify research projects specifically exploring the troubles established academic researchers in the physical sciences have in accessing resources to explore the health effects of manmade chemicals. Previous sociological research has explored the political implications of recognising chemical harm (Boudia et al 2018; Krimsky 2000; 2003), the tendency for authorities to delay decision-making due to uncertainty (Howard 2011); the challenges of regulating environmental chemicals (Jasanoff 1992); and the problems social groups in having toxic environments acknowledged by governing authorities (Frickel 2014; Wynne 1992). In the resource intensive field of the physical sciences, research agendas tend to align with state goals (Cordner, 2015; Knorr-Cetina, 1999) and that without access to funding scientific research is severely constrained or unlikely to proceed (Frickel & Moore, 2006; Latour & Woolgar, 1986).

My review has been unable to locate literature on the dilemma of institutional insiders, such as established researchers with considerable reputational clout, in struggling to secure funding, and the political, economic and cultural barriers that stymy access to funding. In addition, I reiterate Gläser and Laudel's (2016) statement that there is very little research looking broadly at the interplay of state policy and knowledge production (p.117). This has been supported by my own review of the literature. This enables me to predominantly focus on experiences of scientists in achieving funding and the role of governance and funding panel processes.

3. THE CHANGING GOVERNANCE OF SCIENCE

Sociologists Richard Whitley, Jochen Gläser and Grit Laudel (2018) have, alongside colleagues extensively explored the patterns of governance and funding reform and the subsequent impact on scientific knowledge production over the past 3 decades (Gläser & Laudel, 2016; Gläser et al. 2010; Laudel, 2006; Laudel & Weyer, 2014; Whitley, 1984; Whitley, 2010). This section explores the consequences of these reforms on the social, cultural and political behaviour and experiences of funding panels and scientists, and the types of research funding proposal that is favoured as a consequence of these reforms.

The authors have identified four overarching funding and governance changes that have occurred alongside a decline in the rate of increase of funding. First, countries have shifted from recurrent funding to extramural contract-based, contestable funding where scientists compete for funding of scientific research. Second, states have increasingly directed research capacity towards public policy goals. Third, states have increased oversight of activities through standardised assessments, peer review and other measurable indicators. Finally, states have supported and encouraged institutions to ensure research knowledges are protected through patents or potentially commercialised.

These shifts occurred after economic and oil shocks throughout the 1970s and 1980s drew attention to the greater resilience of higher income countries. Science became recognised as a driver of economic growth, and in this spirit, national innovation systems (Freeman, 1995) were encouraged, which emphasising institutional networking, interdisciplinary and local connectivity and knowledge based around problem-driven, output-based Mode 2 knowledge production (Gibbons, et al., 1994). With university research environments situated as a driver of economic growth, academia moved closer to industry, producing a "triple helix" of university-industry-government relations (Etzkowitz & Leydesdorff, 2000), and encouraging "academic capitalism" (Mendoza, Kuntz, & Berger, 2012).

Gibbons et al. (1994) had earlier stressed the importance of Mode 2 inter-and-transdisciplinary science to societal problems, and then later acknowledged the sociopolitical shift, which reduced scientific autonomy while increasing scientific accountability (Nowotny, Scott, & Gibbons, 2003). The global economic downturns and an increasing science enterprise fostered a political climate receptive to increasing oversight and greater accountability of science production. Scientific research became contract based and mission oriented, funding became predominantly accessible through contestable, or competitive, funding systems, and commercial relationships were encouraged (Whitley, 2010; Wright & Shore, 2017). Demeritt (2000) viewed this as a shift towards a new social contract. He argued that the focus on economic growth and commercialism produced a narrow instrumentalism in research, with public value equated with productivity and economic growth. Demeritt (2000) theorised that demands for social relevance and public accountability risked situating the academic enterprise as a 'Trojan Horse for a set of unexamined political and economic commitments' (p. 311).

Innovation logics supported commercialisation norms and the establishment of technology transfer offices (Wright & Shore, 2017). Popp Berman (2012) considered these shifts followed extra-institutional shifts, such as the enactment of the 1980 Bayh–Dole Act (BDA). Implicit in the BDA was an obligation of universities to commercialise inventions. States and academic institutions globally transitioned to adopt local versions of the BDA (Gotkin, 2012).

The four overarching funding and governance changes produced interconnected consequences for scientific research. The specific factors contributing to alter scientific behaviour cannot be empirically analysed. In order to demonstrate this, I have firstly selected three case studies that particularly demonstrate the interconnected and necessarily indeterminate effect. In the text that follows, I review the broader literature within the framework of the four governance shifts. However, I emphasise that a significant proportion of the literature is interconnected and overlapping.

THREE CASE STUDIES

(A) COMPETITIVE FUNDING ENVIRONMENTS. In a study of German and Australian universities, scientists of all calibres adapted to competitive contestable funding environments, selecting low risk, affordable and applied research in order to ensure security. The Australian scientists, who were limited to a single funding agency, were more likely to sell their services and commercialise work, than German scientists. Research quality was impaired. Researchers reported having to downsize, rely on more rudimentary laboratory equipment or abandon projects,

particularly longer-term research. Many of the participants transitioned from basic to applied research, as well as towards more theoretical research, in order to compensate for the absence of suitable laboratories (Laudel, 2006).

(B) UNFAMILIAR RESEARCH PROPOSALS. A 2012 study investigating bias in medical research regarding unfamiliar grant proposal evaluations consistently found that proposals were likely to be marked down if the assessor was in the same research field and if the assessor was a highly cited researcher. Discounting reduced slightly if the proposal was intellectually proximate (Bourdreau et al. 2012).

In 2016 the research group went one step further. Bourdreau et al. (2016) explored the patterns of granting funding allocation in an endocrine-disease related medical research field. They considered the role of 'intellectual distance' and novelty in the approval process. Expert researchers were found to provide more discerning evaluations, but were more likely to discount research in their own field than experts with intellectual distance. Highly novel research which departed from established research was likely to receive a lower evaluation. The authors considered that the barriers to novel research introduced a "form of fundamental uncertainty that cannot entirely be resolved without experimentation" (p. 2769). Bourdreau et al. theorised that this pattern resembled theories of bounded rationality and the problem of high uncertainty, proposing that "established knowledge and mental models are 'brittle,' and this leads to systematic errors in judging new ideas" (p. 2778).

(C) CREATIVITY IN SCIENCE. High scientific creativity is associated with individual researcher autonomy, stable research sponsorship, small group size, leadership, access to a complementary variety of multidisciplinary and technical skills and access to external networks with supporting knowledge and expertise. Heinze et al. (2009) observed that creative scientists often move to new fields or integrate different disciplinary approaches into their area of expertise and that they often have a broad scientific profile rather than deep specialisation. Conventional funding processes could be a barrier to creative work.

> The group leader recalled that one always needs preliminary results in order to compete for external funds. Therefore, getting into a new field without having preliminary results is regarded as "almost impossible." Another group leader argued that "field-hopping is bad for research grant income because it takes five years to build up credibility to get research funding". The current research system does not appear flexible enough to accept that a scientist with an excellent track record in a given field can have the capability to investigate

> a phenomenon that involves moving into a new field and that there are synergies in funding such research. (p. 619)

The study also identified the problem of knowledge lag where scientists progress with new knowledges and programme officers are not able to keep up with developments, and the requirement that research proposals set precise targets and outline expected results (Heinze et al. 2009).

CONTESTABLE FUNDING

The shift to external contestable funding was theorised to create market-like mechanisms that would enhance academic performance and ensure that research more closely converged with broader policy goals (Auranen & Nieminen, 2010). Funding constitutes tacit approval of a research proposal. When science does not fit inside the requirements of funding schemes, panels demote proposals down the list for funding. The technical act of demotion leaves out ethically problematic questions regarding how and why particular forms of scientific research have no related funding pathway.

Contestable environments ensure that science is more likely to conform with state goals, however they are also more likely to produce more conservative research than prize, or block funding environments (Franssen et al. 2018; Laudel, 2006; Wang et al. 2018). Alberts et al. (2014) argue that in the biomedical sciences, low funding success rates alter the chain of scientific knowledge production, inducing "conservative, short-term thinking in applicants, reviewers, and funders" (p. 5774).

In contestable environments, secure, high-status scientists exhibit greater autonomy. With funding limited research groups make use of cheaper graduate students and postdoctoral fellows, while early career scientists remain underutilised (Alberts et al. 2014). Physicist Richard Muller (1980) outlined the dilemma: "It is easy to fund the established scientist who continues to work in his established field. It is risky to fund the scientist working in an area that is not yet established ~ or a young scientist working in a field that has many experienced researchers" (p. 882). In a Japanese study, high-status researchers produced more novel funding proposals in contestable environments, while junior and female researchers demonstrated greater creativity in block-funding environments (Wang, Lee, & Walsh, 2018).

There is an opportunity cost to grant writing that may act as a barrier. Australian health and medical researchers spend on average 38 working days preparing grant proposals, which have a 20%-25%

success rate (Herbert et al. 2013). Success rates in New Zealand are slightly lower (HRC, 2020a; HRC, 2020b).

While funding panels aim to strike a balance between conventional and innovative proposals (Braun, 1998), research that confronts existing norms can be difficult to fund. Researchers have long hypothesised that original or novel research ideas outside currently accepted scientific paradigms are at risk of being dismissed, rejected or marginalised (Fleck, 1935/1979). Picotti et al. (2013) have argued that while a shared scientific method infers epistemic objectivity, new knowledges and technologies can pose challenges to the traditional scientific method.

Scholars have identified that science that is complex, ambiguous and politically problematic, may struggle to be recognised by scientific colleagues (Cordner, 2015; Funtowicz & Ravetz, 1995). EDC research appears to be just this form of science (Boudia, et al., 2018; Howard, 2011; Krimsky, 2000). Scientists attempting to undertake post-normal research in climate change have found themselves stymied by disciplinary conventions (Friedrichs, 2011) and risk assessment panels have been unable to negotiate the ambiguities considered normal by EDC researchers (Honkela et al. 2014). Ambiguity lends itself to ambivalence. As Hajer and Laws (2018) have noted, "ambivalence confounds choice as an organizing metaphor for action' and ambivalence 'lends itself to suppression" (p. 2).

Rather than increasing research output, hypercompetitive funding environments may stymie productivity. Publication output is an important metric to establish the success of funding, however, Auranen and Nieminen (2010) reviewed eight countries to understand the degree to whether competitive funding environments resulted in increased productivity, increased publication output, but could find no evidence. Their result led them to query whether hypercompetitive environments instead caused harm through an "emphasis on quantity instead of quality, orientation to less innovative, mainstream research and weaker societal impacts in the long run" (p. 831).

APPLIED VERSUS BASIC/MULTIDISCIPLINARY

Basic and applied research are interdependent and research projects often traverse both forms of research (Rushforth et al. 2018). While combinations of basic and applied science are common, funding panels appear to deprioritise the more ambiguous and broader field of basic science (Bentley et al. 2015; Risbridger, 2015).

A 15-country study by Bentley et al. (2015) identified that environments conducive to basic research were less likely to emphasise output obligations. In the study, China and Norway had the

highest proportion of basic researchers, while Australia and Argentina had the lowest proportion. Grove (2017) examined the effects of funding policies on academic research, finding that the major factor ensuring maintenance of research agendas was whether their work was applied, noting that they were at "an advantage when it comes to winning grants due to the increasingly directed nature of most funding" (p. 192).

Multidisciplinary projects may carry considerable risk in competitive funding environments (Laudel, 2006; Rip, 2011). Guimarães et al. (2019) argued that current research environments are not adequately prepared for the inter- and transdisciplinary research. The uncertainty and entanglement of the grand challenges, the tendency to disciplinary isomorphism and the historic approaches of academic research environments have not supported these research modes (Guimarães, Pohl, Bina, & Varanda, 2019).

ABSENCE OF SLACK IN THE SYSTEM

Flexible research environments promote creativity (Heinze et al. 2009). Azoulay et al. (2011) found that longer windows for researcher-led schemes were more forgiving for early-stage failure, and instead potentially encouraged scientific creativity. By contrast, highly contested funding environments lead to an absence of slack and diminished autonomy. Muller (1980) identified that tightening of funding reduced the probability scientists would commence novel side-line projects that required investment in time and resources. Such projects were too undeveloped to be accepted through the formal funding process. Other scholars have found that the absence of slack to conduct explorative research, amplifies the status quo (Franssen et al. 2018; Moore et al. 2016). Fortin and Currie (2013) suggested large grants directed to elite researchers may not produce more impactful science than funding supplying more diverse groups of researchers. Wang et al. (2018) recognised the disruptive potential of small teams, whereas large teams developed existing ideas.

STATE GOALS

In 1957 Robert Merton remarked that "scientists tend to develop the values and to channel their motivations in directions the institution defines for them" (p. 640). Scientific research is expensive and in New Zealand the state is the major investor in health research funding. Whitley (2010) contended that while authority relations vary significantly by country, where funding is

> highly stratified and funding is dominated by a small number of research foundations, attempts to institutionalize a competitive market for resources based on the excellence of individuals' and departments' contributions to collective intellectual goals are likely to

> reinforce both existing prestige hierarchies and researchers' dependence on the standards and goals of current scientific elites. (Whitley, 2010, pp. 36-37)

Competitive funding processes more tightly bind science production to state priorities than via block or prize funding. States and funding schemes have identified priority areas for the allocation of funding. Central to this has been the move to implement policies to support innovation, with the understanding that innovation drives economic growth and national wealth (Popp Berman, 2012; 2014; Schot & Steinmueller, 2018; Stern et al. 2000). Innovation has been a central pillar of New Zealand science policy for 2 decades (Leitch et al. 2014; MBIE, 2015).

Barriers can arise for scientists whose proposals do not conform to standardised schemes. Laudel and Weyer's (2014) study of the reform of the Dutch science system to increase accountability and ensure science production reflected state goals, identified that in the process universities and academics lost authority over research topics. While standardised funding mechanisms created quasi-markets for research, this could also produce quasi-market failure, promoting the disappearance of small disciplines (p. 136). Another Dutch study compared competitive project-based funding to prize funding. Researchers approached competitive funding with static proposals designed to conform with schemes. These proposals were inherently conservative. In contrast, prize funding offered researchers "organizational slack". Researchers were able to develop innovative ideas, and flexibly alter them, without strict evaluative protocols (Franssen et al. 2018, p. 32).

Excellence, a proxy for quality, threads through policy literature. Excellence-driven research policies emphasise the quality of research and the peer review process for allocation of funding. Excellent research is recognised by top journals and highly cited. However, Ferretti et al. (2018) draw attention to the difficulty of achieving excellence, considering excellence a contested concept, and query the indicators used in applying standards of excellence and the value frame associated with these indicators. The challenge of maintaining quality while promoting originality remains a dilemma for scientific research. Moore et al. (2016) argue that hypercompetitive environments stressing excellence and impact drives a 'circular conservatism' and reinforces existing powerstructures (p. 10). They argue cultures emphasising excellence have difficulty identifying high-quality novel or original research, but that these cultures also risk marginalising normative science looking to validate existing knowledges.

ADMINISTRATIVE OVERSIGHT

Meso-level governance institutions have increased their oversight of the funding process. Evaluations of research performance have evolved over three decades to become an important

mechanism of state oversight of universities and university management to ensure accountability for research. Funding schemes have become increasingly standardised evaluation procedures (Whitley et al. 2018). Scientific peers engage in peer review of funding proposals to determine grant funding. The peer review process of self-governance by the scientific community is undertaken to ensure science is of appropriate quality, and to ensure accountability for the public funds scientists receive (Chubin & Hackett, 1990).

Latour (1987) described political institutions as "obligatory passage points" scientists must navigate in order to secure approval to undertake research. Stark (2014) describes "declarative bodies" as the governing groups that oversee the rules that umbrella the funding and consequent research process. Stark draws attention to the:

> The seemingly small and mundane changes that ethics review committees, editorial boards, and funding panels request researchers alter how they talk to their informants and patients, as well as how they move around their field sites and laboratories. Because of the material and symbolic resources at stake, researchers tend to comply with this new form of rational authority based on science by which their work is governed. (Stark, 2014, p. 451)

The knowledges of these groups are drawn from the cultures that surround them, and reflect their expertise, pragmatisms and the political orientations of the institutions they associate with (Stark, 2014). Sheila Jasanoff has written of the vulnerability of peer review to "special scrutiny as more political actors recognized it as a space for flexible judgment" (Jasanoff & Simmet, 2017, p. 27).

The social worlds of scientist peer groups as funding panel members, can drive the production of certain forms of science. Peer groups contain variants of social capital and epistemological authority, and over time funding panels develop their own "social systems" – norms and values which direct the group towards certain preferences (Bourdieu, 1986; Braun, 1998). Panels form social bonds and disciplinary coalitions that may then influence whether science outside established research areas – new paradigms – are accepted. Scientists tend naturally to collegiality and are likely to trust colleagues in familiar disciplines (Braun, 1998; Oreskes & Conway, 2010). When an influential expert reviewer supports a grant associated with their discipline, approval for funding is more likely (Li, 2017). There may also be a moral component. Becker posited that "social groups create deviance by making the rules whose infraction constitutes deviance and then applying those rules to those people who deviate and labelling them as outsiders" (in Kapstein, 2019, p. 1139).

Institutions play an important role in validating knowledge. Consensus in science is the result of social processes of negotiation, and science cannot be recognised until there is a theoretical basis to

support it, and a language to describe it (Latour & Woolgar, 1986). Merton (1957) envisaged originality as key, as 'through originality, in greater or smaller increments, that knowledge advances' (p. 639). The process of peer review is inherently conservative, and the process of peer review involves the navigation of risk, either because scientific research is not novel enough, or is too novel and unfamiliar (Hackett, 2005). Expert disciplines frame uncertainty and risk differently (Althaus, 2005). As Gieryn (1995) and others have noted, elite groups engage in boundary work to establish which science is credible (Kuhn, 1970). Latour & Woolgar (1986) documented how the settling of an objective fact involved navigation of consensus-forming processes and the settling of controversies. In practice, scientific objectivity may be more likely to reveal a state of scientific consensus, rather than truth (Ezrahi, 2003; Kuukkanen, 2012). Kuukanen (2012) envisages scientific objectivity as intersubjectivity. The degree to which science or deliberation is viewed as objective is dependent on the degree to which it has 'been exposed to critical reflection from various points of view, and, as a consequence of this, transcends inevitable subjective idiosyncrasies' (Kuukkanen, 2012, p. 310).

While peer review is configured to encourage impartiality, "variations in the interpretation and application of epistemic norms and values are almost always conceived of as problematic" (Lee et al. 2013, p. 3). Disciplines, cognitive cultures and methodologies can vary markedly (Braun, 1998), and impartiality is difficult in practice, due to different values, biases and risk tolerances (Lamont, 2009; Lee et al. 2013; Long & Fox, 1995). Homophily, the preference for the familiar, extends beyond shared professional characteristics, to preference for gender and country (Murray, et al., 2019). The logics that incentivise universities, peer review panels and boards to privilege academics who have published in top-tier journals (Merton, 1979) do not necessarily reflect the logics of scientists (Chavarro et al. 2016). Bias can also arise from preferring a particular kind of result, such as a specific output (Risbridger, 2015) or studies that exclusively reveal positive effects (Chavarro et al 2016). A 2015 computer simulation modelled how grants might be scored against "non-preferred" investigators. The exercise demonstrated that non-preferred investigator researchers were required to submit much higher quality grants in order to receive funding (Day, 2015). Reviews can be swayed by prestige of university, the quantity of reviews an assessor considered, and whether a lead author was a professor (Jayasinghe et al. 2003).

Peer review panels struggle with judging unfamiliar or novel research proposals (Muller, 1980; Bourdreau et al. 2016; Roy, 1985). Travis and Collins (1991) argued that cognitive similarities create barriers to novel research, noting that "interdisciplinary research, frontier science, areas of controversy, and risky new departures are all the more likely to suffer from cognitive cronyism than is mainstream research" (p. 336).

In a paper exploring biomedical research funding, Horrobin (1990) queried that peer reviewers placed a disproportionate focus on quality control and demonstrated less capacity to recognise and promote innovative research projects. Chubin and Hackett (1990, pp. 60-65) reported that the rejection of funding proposals often meant that scientists dropped particular lines of work, noting that "60% of the respondents to one survey believe that reviewers are reluctant to support unorthodox or high-risk research" (in Laudel, 2006, p. 490). Groups may be more likely to dismiss outliers than individuals (Minson, 2012). Gläser et al. (2010) observed that scientists design their research to dually conform to behavioural expectations and align with the research practices and epistemic norms of their field of expertise.

PRECARITY

Precarious funding environments privilege higher status researchers, and steer less established researchers towards more conservative research (Anderson et al. 2007; Edwards & Roy, 2017; Wang et al. 2018). Women and ethnic minorities are at greater risk of non-funding (Fang & Casadevall, 2015). Sigl (2016) observed that researchers with precarious incomes experienced both epistemic and social uncertainty and ensured research conformed to norms in order to sustain their income.

Incentivisation measures such as performance-based funding which rewards experienced researchers, may negatively impact younger researchers (Buckle & Creedy, 2017) and Māori (Roa et al. 2009). Scientists abandon worthy projects when institutional elites declare a project 'done'. The action of abandoning research becomes habitus, normatively accepted and invisible to the scientists (Jeon, 2019). In order to progress research that may not be prioritised by institutional actors, scientists undertake unfunded research, often self-funding and pursuing work outside of working hours (Edwards, 2020).

COMMERCIALISATION

Over the past three decades, governments and institutions have implicitly and explicitly created mechanisms to steer research discoveries towards the patenting, licensing and commercialisation of public research (Gläser & Laudel, 2016; Whitley et al. 2018). Biomedical science through the process of biological discovery and the potential to identify new technologies in diagnostics, treatment, and clinical care that can be potentially commercialised, has enhanced the potential for this sector to be resourced. Medicine is the most highly cited research field in New Zealand (MBIE,

2018) and research funding contracts impose considerable obligations on researchers to secure intellectual property rights for research (HRC, 2018).

Conditions of financial uncertainty can increase the likelihood research will dovetail with commercial aims. Slaughter and Leslie (1997) interviewed faculty involved in research projects likely to result in technology transfer. Faculty were more likely to be applied scientists or from professional schools who whose research had entrepreneurial potential. The authors found that researchers did not directly embrace commercial norms, instead they "elided altruism and profit, viewing profit-making as a means to serve their unit, do science, and serve the common good" (p. 252).

> We found that as professors sought more applied funds as money for basic research was curtailed, they began to define themselves as inventors and entrepreneurs and sought to negotiate contracts for themselves, to understand patent law and markets for scientific products and processes. They knew if they did not sit at the table with industry and government, they would not be players. They developed extensive entrepreneurial knowledge to protect their autonomy, prestige and expertise. (p. 252)

'"EXOGENISING" UNCERTAINTY

The four themes act to exclude ambiguous and uncertain research. Wynne (1992) has highlighted the active role of ignorance, the linkages between biological, social and cultural elements that reduce the capacity for harm to be recognised, noting that when science proceeds by "exogenising" uncertainties, they then become invisible (p. 115). Barriers to knowledge production that arise when experts avoid extra-scientific situations of uncertainty and indeterminacy (Wynne, 1992). The framing out of knowledges relating to human health harm produces a form of ignorance, undone science, which can prevent or delay social groups and sympathetic experts from seeking justice (Hess, 2020) and can frame out nasty surprises (Howard, 2011).

Authors have suggested that innovation is not an end of and in itself. Schot and Steinmueller (2018) suggest that innovation must be, instead, directed by values that acknowledge the potential for human activities to destabilise environmental planetary boundaries, such as, for example where environmental tipping points destroy the viability of species survival and freshwater systems (Steffen, et al., 2015). Schot and Steinmueller (2018) have emphasised that innovation cannot be equated with social progress, having led, too often, to inequality, excessive consumption and pollution. Instead, the authors suggest innovation as sociotechnical, explicitly political and embedded in transformation.

In many ways they echoed Guston et al.'s (2001) argument that policies aligned to economic development and commercial innovation marginalise science policy, reducing the potential for socially relevant science. In a similar vein, Ravetz (2011) has asked that we look to the contradictions of society, which relate to the control of knowledge, the incapacity to acknowledge uncertainty and ignorance, the absence of values guiding science and the failure to address the consequences of science-based industrial systems (Ravetz, 2011). This resonates with Slaughter's (2012) call to take the signals of increasing risk, such as planetary boundaries (Steffen, et al., 2015) seriously, and cultivate skepticism about the assumed importance of science and technology.

Jeff Howard (2011) envisaged endocrine disruption as an *environmental nasty surprise* (ENS). ENS's are environmental problems that catch institutional actors and the general public off guard; are extensive by the time they are widely recognised; result from entrenched technological processes, practices and systems; and present a large-scale, long-term risk to human or ecological health. Howard argues that these nasty surprises inevitably arise in environments where the entrenchment of prevailing power structures, and "extraordinary political clout" of industry, and the hegemony of the knowledge paradigms that support them, dwarf any attempts to counter-balance the status quo. The complexity in these environments require a post-normal (Funtowicz & Ravetz, 1995) approach, as both decision stakes and systems uncertainty is high, and as Howard maintains, the problem is 'deeply rooted in entrenched technological systems and hence especially resistant to correction' (Howard, 2011, p. 189).

4. CONCLUSION

Even as lower-level health research policy emphasises public good research (HRC, MBIE, MoH, 2019), the higher-level policy and government reports emphasise the importance of innovation, excellence, the measurability of publications and intellectual property protection mechanisms (MBIE & MoH, 2017; MBIE, 2018). Hypercompetitive funding environments appear to ramp up risk, increasing the potential for conservatism in both funding proposals and funding panel decisions, discounting and displacing novel and unfamiliar science. Tightly supervised funding grants leave limited space for explorative, curiousity driven research. Stensaker and Benner (2013) have theorised that 'global scripts and templates' about what is 'entrepreneurial' can 'lock-in' universities to generic development paths and leave them unable to respond to local conditions. While Scandinavian universities are conforming with 'global ideas of what a 'modern' and

‘innovative’ university must do’, Stensaker and Benner contend that standardised approaches have left universities in a sort of ‘strategic inertia’ (p. 414).

Chapter 4. New Zealand's Innovation Mindset

1. INTRODUCTION

Governing institutions and policy instruments affect scientific knowledge by creating political, social and cultural climates that foster and sustain particular forms of knowledge production. Taken for granted, normative expectations at the policy level and at the funding level, are a product of three decades of policy privileging economic growth. These processes steer physical science research further towards the production of applied knowledges inside the health sector.

New Zealand's governance transition over the past three decades echoes the global pattern outlined by Whitley et al (2018) in Chapter Three. First, health research funding became available through external contestable funding mechanisms. Second, state goals are incorporated in science policy. Third, successive rounds of reforms increased bureaucratic oversight and standardisation of scientific activity, particularly in academic and health research. Fourth, *innovation, investment, excellence*, and *translation* discourse complement and embed biomedical norms to emphasise research outcomes which have potential to be commercialised.

Firstly in this chapter, I briefly outline shifts in governance, academia, the health sector and science production in New Zealand that have entrenched market norms of competition, accountability and economic growth across public sector life. Secondly, I draw attention to the key neoliberal and NPM concepts emphasising financial return, accountability and economic growth that are prevalent throughout New Zealand science policy literature.

This chapter outlines the historic and discursive shifts across the governance landscape with the aim of shedding some light on the epistemic dependencies (Hardwig, 1985). By considering policy as discourse, attention can be drawn to the way policy makes truth, 'rather than focusing on how people make policy, attention turns to the way policy makes people' (Bacchi & Goodwin 2016).

2. MARKET LOGICS: REFORM IN NEW ZEALAND

New Zealand's economic transformation in the 1980's from state-led relatively protected economy to a deindustrialised, financialised market-led global player was one of the most dramatic and far reaching in the world. Dubbed 'the New Zealand experiment', the transition to democratic capitalism was accompanied by trade and investment liberalisation; privatisation, increasing public

debt; a decline in manufacturing and union power; the ascent of key commodity export sectors; and transition to public-private partnership frameworks of social infrastructure (Kelsey 1997). Successive waves of market-oriented reforms that impacted the public sector, from lean government and privatisation in the 1980's; to roll-out reform to protect the functioning of free markets, such as via trade agreements that protect offshore investment; to roll over as economic logics and individualised responsibility were locked in (Brenner et al. 2010; Humpage, 2014). While positioned as apolitical, state functions were repositioned in favour of "politically guided intensification of market rule and commodification" (Brenner et al. 2010, p. 184).

ACADEMIA

University research environments were reconfigured. Alongside the fundamental university occupation of research and teaching, universities were tasked with an entrepreneurial third mission, that of the production of innovation that directly supported economic development and productivity (Philpot et al. 2011). University administrations and staff were encouraged to reflect private sector norms, and "industry-academia collaborations, spin-off companies, and patenting of research results" (Mendoza et al. 2012).

Economic transformation inserted private sector, or neoliberal values of innovation, productivity, efficiency into academic life. New Zealand universities underwent substantial reforms from the 1980's onward, introducing fees and student loans; and developing patent offices and private companies to manage commercial opportunities (Wright & Shore, 2017). New Zealand universities followed the United Kingdom to implement New Public Management (NPM) audit and funding systems. NPM systems focus on cost accountability, contract management, decentralisation (Gruening, 2001). New Zealand followed the United Kingdom, Australia and Hong Kong and implemented performance-based funding (PBF) research evaluation systems (Buckle & Creedy, 2017).

HEALTH SECTOR

The New Zealand health sector restructured along lines emphasising accountability and performance monitoring (King, 2001; Upton, 1991). The influence of neoliberal policies implemented in the 1980s and 1990s positioned health reform under a new public management (NPM) paradigm (Prince et al. 2006).

New Zealand health reforms consistently reinforce health policy in a discourse of health care inside the health sector. The 2001 New Zealand Health Strategy (NZHS) developed and implemented by

the 2001 Labour government (King, 2001) placed the bulk of responsibility for reducing the growing burden of non-communicable disease inside the health sector (Tenbensel et al. 2008). King's policy had been unique in acknowledging the social determinants of health and the need for cross sector policy development outside of the health sector, (King, 2001; Prince et al. 2006).

The New Zealand Health Strategy replaced the NZHS in 2016, positioning health as a dual responsibility of consumers and the health sector (Minister of Health, 2016). King's earlier acknowledgement of broader social determinants of health were dropped. The 2016 document emphasises the necessity of systemwide health-sector integration and the importance of the Treaty of Waitangi. The strategic orientation of the policy focuses on key themes relating to the functioning of the health sector and does not discuss upstream drivers of the burden of chronic disease.

OUTPUT BASED SCIENCE

New Zealand's science system has been progressively reordered as a national innovation system tasked with achieving economic growth. Research, science and innovation are envisaged as the 'key lever' to increasing economy wide research and development investment (MBIE, 2018).

Scientific research has historically supported key export industries. A single autonomous institution, the Department of Scientific and Industrial Research (DSIR) directed science research in New Zealand from the 1920s to the 1980s. In 1989 government officials shifted this to a tri-institutional framework. The Ministry of Research, Science and Technology was established with responsibility for policy development, while the Foundation for Research, Science and Technology, (FRST) allocated research funding. The FRST allocated science funding for the "production of outputs relating to public good science and technology" until 2011 (PCO, 1990, p. Sn.2.). The DSIR was dissolved in in 1992. Staff from DSIR and other agencies were integrated into 10 Crown Research Institutes (CRIs) who are expected to return a dividend to the Crown (SFU, 2010).

From 2011 science production was politically positioned within an economic and productivity frame. Following FRSTs dissolution in 2011, the Ministry for Business, Innovation and Employment (MBIE) secured responsibility for administering the bulk of research, science and technology funding under the Research, Science, and Technology Act 2010 (PCO, 2010). With this shift, New Zealand's science enterprise transitioned to one where primary oversight was by business facing agency tasked with driving the governments growth agenda (Leitch et al. 2014, p. 122).

The new legislation excluded reference to the public good. Instead, science production was "for the benefit of New Zealand" with science for economic growth included as a purpose for funding (PCO, 2010). An important but subtle point is that where "public good" (PCO, 1990, p. Sn.2.) had been previously defined, the new term "benefit" lacked interpretation, imposing no clear obligation on the MBIE (PCO, 2010). The primary purpose of the MBIE, "to grow New Zealand for all" (MBIE, 2020b) reflects the orientation of the 2010 act.

MBIE has responsibility for most of New Zealand's science funding. IN 2015 MBIE released a science strategy which prioritised the production of excellent, impactful science designed to enhance economic growth (MBIE, 2015). With oversight of the majority of the science budget, MBIE wields substantial power over the New Zealand science enterprise (MBIE, 2020a). In this context power is 'the ability to influence others directly or indirectly, subtly or overtly, legitimately or illegitimately' (Frickel & Moore, 2006, p. 8) In the 2020 budget, allocations for science, research and development exceeded $1.7 billion with MBIE responsible for 78% of science funding (Treasury, 2020a; 2020b). MBIE directs resources to the Health Research Council (HRC) and Marsden Fund as contestable funding, and to the National Science Challenges (NSC) as non-contestable (but reviewable) funding (MBIE, 2020a).The Tertiary Education Commission administers the Centres of Research Excellence (CoREs) which are contestable. The NSC and CoRE schemes provide longer term funding.

HEALTH RESEARCH COUNCIL

The Health Research Council (HRC) of New Zealand was established by an Act of Parliament in 1990. The HRC replaced the Medical Research Council of New Zealand which had operated for over forty years. The HRC uniquely focusses on health and is the 'primary vehicle for government investment in health research' (MBIE, 2015, p. 36). The HRC operates three research streams biomedical, public health as well as a stream for research impacting Māori. While biomedical research concerns research into the causes, consequences, diagnosis, and treatment of human illness, public health research explores the environmental, socio-economic, cultural, and behavioural factors that determine health status (PCO, 2014). In 1995 the New Zealand Association of science was concerned that biomedical research was substantially underfunded, and advocated for increased prioritisation (Gregory, 2016). The weighting of funding to each research stream remains unclear.

The Ministry of Health has oversight of the legislation guiding the HRC, however, funding for HRC is secured through the MBIE (MBIE & MOH, 2015). Funding for the HRC has stagnated. Despite a

recent surge in funding from $84 million in 2012/2013 to $117 in 2020, funding continues to lag behind comparable countries (Reid et al. 2014). Current funding not only remains low but is dwarfed by the health system costs of non-communicable disease. A recent paper estimated that New Zealand government spent US$26.4 billion managing non-communicable disease over a seven-year period (Blakely et al. 2019). New Zealand's substantial burden of disease has not been matched by a commensurate commitment to understanding the factors driving the expanding burden of disease. The 2020 allocation to the HRC remains less than ten per cent of the total science budget (Treasury, 2020a).

The HRC budget increase was accompanied by policy aligning health research more closely with the National Statement on Science Investment, which stressed impact, excellence and innovation. This shift signalled greater oversight and direction from the MBIE, and greater alignment with MBIE principles. These values were further emphasised with the release of the New Zealand Health Research Strategy by the MBIE and the Ministry of Health in 2017 (MBIE & MoH, 2017). While the legislation directing the HRC provides responsibility for the production of scientific knowledge that leads to the protection of health, the MBIE envisages science production that results in economic benefit through the production of innovative goods, services and processes. The HRC's guiding legislation does not mention innovation, economic growth or investment. The purpose of the HRC was initially envisaged to improve human health by promoting and funding health research (PCO, 2014).

For individual scientists, the HRC is the most likely source of health research funding. New Zealand HRC funding has around a 12% success rate (HRC, 2020b) while Explorer Grant success rates are around 20% (HRC, 2020a).

3. POLICY REFORM

POLICY DISCOURSE AND INNOVATION

This section explores the discourse on innovation and the concordant terms investment and excellence as they course through policy documents. Discourse has been described as the software that directs institutional life. Discourse guides action, establishing the meanings, identifying objects for action, confirming relations between facts, values and actors, and sets the boundaries defining legitimate knowledge (Dryzek 2008).

> Discourses establish meanings, identify agents in contrast to those who can only be the object of action, confirm relations between actors and other entities, set the boundaries for what is legitimate knowledge, and generate what is accepted as common sense. (p. 2)

For FP's and scientists, policy discourse creates conditionalities around what is expected and normative. Discourse analysis can be applied to reveal the themes and nuances that are repeated in language, as a form of deliberative rationality. Ball (2015) writing on the role of discourse in policy, noted Foucault's insistence that the structures and rules that arise out of discourse should be observed. Messages could not be reduced to a given text. Ball notes that discourse is more nuanced than language "Discourse is not present in the object, but 'enables it to appear' elaborating that 'Discourse is the conditions under which certain statements are considered to be the truth" (p. 311).

NEW ZEALAND HEALTH RESEARCH STRATEGY

The 2017 New Zealand Health Research Strategy (NZHRS) is a joint policy document by the Ministry of Health and the MBIE. The NZHRS outlines the principles, clarifies common terms, and shapes the weighting of priorities that drive decision-making for governance bodies and panel members, and guide scientists applying for health research funding.

The Health Research Strategy has a sound vision, to improve the health and wellbeing of all New Zealanders, and within this research excellence is well and appropriately defined. The guiding principles: research excellence, transparency, partnership with Māori, and collaboration soundly apply to research exploring health at the societal, biological or epigenetic level. These principles are developed to guide the strategic priorities. These seek to reduce health inequities, foster inclusive policy setting, encourage collaborative research environments, and aim to build pathways to translate research findings into policy and practice. Again, prima facie, these terms apply equally to science conducted at the social, biological or epigenetic level.

The first action following the release of the NZHRS was engagement to establish a priority framework. The Health Research Prioritisation Framework (HRPF) assists funding panels in decision-making to prioritise funding investments and is designed to harmonise with the NZHRS (HRC, MBIE, MoH, 2019). The Health Research Prioritisation Framework softens many of the NZHRS aims, emphasising the importance of promoting wellbeing in a New Zealand context and emphasising the importance of mātauranga Māori (HRC, MBIE, MoH, 2019).

While the HRPF provides guidance, there is no definition of terms. In this context, both the National Statement of Science Investment (NSSI) (2015) and the NZHRS (2017) remain

authoritative policy documents, with the definitions contained in these documents actively informing downstream policy. For physical scientists seeking funding for research, the terms imply specific outcomes, and these terms will be understood by funding panels. Therefore, I consider how these terms are applied in the NZHRS in order to understand both the implications in the HRPF, and the implications for funding panels and scientists.

ASSUMING WELLBEING: A CONSEQUENCE OF ECONOMIC GROWTH

The subtle ways text is presented, and the dominant terms allocate agency to some actors while excluding others. The accumulation of terms in discourse provides a meaning and motivation provides agency for some actors while placing other actors outside the narrative scope.

The primary science policy document for New Zealand, the NSSI refers to *investment* over 150 times, *innovation* 95 times, and *productive/productivity* – 47 times. *Excellence* is referred to over 60 times and *impact* 100 times (MBIE, 2015). The NZHRS the primary health research policy, refers to investment over 40 times, and innovation around 100 times, translation 50 times. Excellence is referred to 28 times, impact is discussed and cited over 30 times, and translation some 50 times.

As translation is a biomedical term, it is not expected to be included in the NSSI. The NZHRS defines biomedical science but does not discuss or define environmental health science. Clinical research is discussed at length, but not basic research, which can drive ongoing exploration in science. Commercialisation of research is discussed in depth, but the potential for research to support policy and regulatory systems to protect health is not discussed (MBIE & MoH, 2017).

Terms that could be used to guide research for the express purpose of protection of human health are left outside the policies or remain ambiguous. First, health, or wellbeing is envisaged as an outcome of economic growth. The NSSI emphasises that growth and productivity will enhance wellbeing with the Minister's Foreword claiming "Innovation will be the main mechanism through which we lift New Zealanders' productivity, prosperity and wellbeing" (MBIE, 2015, p. 4). In this context, science is expected to grow the economy, and the consequent rise in productivity will increase living standards. Historically important terms such as "public good" are not included in the policy. While the NSSI mentions wellbeing as an outcome of economic growth, the NZHRS does not mention wellbeing, and protection of health is limited to references relating to equity of care and the protection of research participants. Secondly, the focus for the NZHRS is on the development of interventions, processes and innovations that are intended for application inside the health sector. This issue of application focussed inside the health sector is discussed in more detail in the next chapter.

The consequence of sustained discourse that integrates industry terms and references, is the creation and perpetuation of industry and growth central paradigms. “Power is internal to discourse” (Dryzek 2008, p. 2) and discourse reflects existing power relationships (Newton, Farrelly, & Sinner, 2020). Discursive norms become embedded in the cultural paradigm of actors who are successful in navigating these frameworks, and work within them.

INNOVATION

National Innovation Systems (NIS) are dynamic social systems producing knowledge that can be captured as particular forms of value to drive economic growth and productivity. Innovative industries cluster in regional hubs and overlap as global networks (Freeman, 1995; Stern et al. 2000).

In 2000 a paper was released that pivoted New Zealand’s science enterprise from a research focus to directly position investment in innovation as a generator of national wealth. In 2000 science became a “tool for achieving the government’s social, economic and environmental objectives” (Leitch & Davenport, 2005, p. 899). The transition to economic growth and innovation logics was driven by central government and primarily achieved through policy discourse, communications and structural change (Leitch & Davenport, 2005; Leitch et al. 2014).

What is innovation? Innovation can be both a process and an outcome, it is a source of competitive advantage, either for a nation state, an industry or an organisation. The NZHRS applies the OECD (2005) interpretation of innovation as “the implementation of a new or significantly improved product (good or service) or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations” (MBIE & MoH, 2017, p. 40).

In order that the intent of this term is clearly outlined, I emphasise that knowledge-production is only one of four dimensions of innovation, which also implies the production of novelty, active implementation and value creation. *Knowledge* relates to the ‘understanding of information and the ability to use information for different purposes’ (OECD, 2018, p. 46), and knowledge transfer is a major component of innovation. *Novelty* concerns the uniqueness of a product or process. Prior to the development of national innovation systems, in many ways, science production oriented around these first two elements. However, contemporary norms of innovation include *implementation*, and for the OECD “[i]n order for a new idea, model, method or prototype to be considered an innovation, it needs to be implemented” (p. 47) and made available to internal or external sources. With this construct, a project is not viable if it is not implementable. The fourth dimension, *value*

creation, recognises that innovation is an economic activity. The capacity to value the innovation is important in policy in order to promote innovation that produces beneficial social and economic outcomes (p. 48).

Therefore for governing institutions applying OECD definitions, innovation in the public sector focusses on production of an invention, good or service that can effectively be measured or priced. Knowledge transfer occurs through intellectual rights-based mechanisms and material and data transfer (OECD, 2018, p. 131).

Innovation has replaced research and development (R&D) as the normative term of scientific enterprise. R&D is exclusively concerned with knowledge production:

> 'An R&D activity must meet five criteria: (1) be aimed at new findings, ie, novel; (2) based on original concepts and hypotheses, ie, creative; (3) be uncertain about the final outcome, ie, uncertain; (4) be planned and budgeted, ie, systematic; (5) lead to results that could be possibly reproduced, ie, transferable and/or reproducible [OECD Frascati Manual]. All R&D activities are innovation activities, but not all innovation activities are R&D activities' (MBIE & MoH, 2017, p. 41).

For policy-makers, the shift from an R&D to an NIS infers an output based system. NIS's are primarily tasked with production of innovative technologies that foster national wealth. As Leitch et al. (2014). noted, "the policy pendulum has swung so far that the science system appears subsumed within the NIS" (p. 120). Innovation is, in management literature, an apolitical construct. Innovation is an end of itself. Scientists can apply themselves to researching the critical problems of humanity, but their research must have an innovative outcome.

INVESTMENT, EXCELLENCE AND IMPACT

The use of *investment* problematises the production of uncertain research that does not constitute an investment. The Oxford dictionary defines investment as an action or process of investing money for profit, a thing that is worth buying for future profit, or an undertaking that produces a 'worthwhile' result. Both investment and innovation are framed in such a way that denotes certainty in a future outcome.

The use of the term *excellence* contains a message to researchers as funding will not be secured unless it conforms with normative approaches to scientific excellence. However, there is no single definition of excellence, and excellence is difficult to identify in research environments. Moore et

al. (2016) argued that excellence is a rhetorical device used to claim value and foster consensus within disciplinary contexts.

Impact is closely associated with excellence. Both the NSSI and the NZHRS emphasise that impact is not merely the quantity of citations a scientific publication receives. Impact is emphasised to be: "the direct and indirect 'influence' of research or its effect on an individual, a community, or society as a whole, including benefits to our economic, social, human and natural capital" (MBIE, 2015).

However, scientists will be aware that in competitive environments, when the calibre of science is difficult to judge, it is not unexpected that a FP will turn to an investigators' publication record. Both the NSSI (pp. 36-37) and NZHRS (p. 36) discuss the citation impact of New Zealand publications and the higher-than-average achievement in citations in the biomedical field. The most recent Research, Science and Innovation System Performance Report (MBIE, 2018) links research output to citation impact. In addition, economic impact is clearly measured by "the proportion of inventions which are patented or licensed" (p. 97).

The social and economic benefit of science is extraordinarily difficult to measure, as the knowledges can have benefits that extend decades into the future (Archibugi & Filipetti, 2018). Indicators of success have never been well developed. The MBIE initially configured excellence and impact narrowly to scientific output and publishing history (MBIE, 2015). This appears to have recently softened to include a greater range of social factors, including a prescriptive outcomes-based approach which integrates the Treasury Living Standards (MBIE, 2019a). A science consultation to introduce a public good approach in decision-making does not appear to have been completed (MBIE, 2019b), so I conclude that scientific excellence remains equated with publication history.

The value of innovative science is approximated through the tally of invention disclosures, patent applications or license agreements and the total amount of license income earned. This then helps universities and public sector organisations inform policy and enables them to benchmark knowledge production (Arundel, 2016). Not all disciplines contribute to this process equally, "A university that focuses on law and the humanities is likely to have far fewer opportunities for knowledge transfer than a university that focuses on science, technology and medicine" (Arundel, 2016).

The level of patent applications remains an acknowledged proxy for economic growth (Hasan & Tucci, 2010). R&D expenditure as a percentage of GDP can indicate success, as can patent and

licensing agreements, and New Zealand has a 2% expenditure target. Lundvall (2016). suggests "the most relevant performance indicators of national system of innovation should reflect the efficiency and effectiveness in producing, diffusing and exploiting economically useful knowledge" (p. 90).

Logics that underpin the securing of patents and the consequent potential for licensing income may steer science away from public good science. As Delgado and Am noted (2018) when discussing dilemmas facing the production of responsible science "issues of public concern may not necessarily overlap with the grand societal challenges identified by institutions, and perhaps they are not in accordance with demands for innovations that create market revenues" (p. 4).

TRANSLATION AND INTERVENTION

While *translation* generally infers a beneficial effect where scientific knowledge is not merely produced, but applied in the real world; the term has a specific biomedical meaning which I argue signals FP's to prioritise a particular form of science. The NZHRS conceptualises translation as the "development of new products, processes and approaches" and the "implementation of those new products, processes and approaches into policy and practice" (p. 19). The aetiology of translation is explored more deeply in Chapter 5. Applications are envisaged as being inside the health sector (MBIE & MoH, 2017, pp. 19-21). Funding panels will prioritise translatable research that can be practically integrated by health-related NGOs, district health boards, clinicians, or the Ministry of Health. This can occur through population level interventions, behavioural changes, clinical applications or new treatments.

Public health is commonly occupied with the production of appropriate *interventions* to reduce the health burden. Intervention is defined following World Health Organisation criteria: "Interventions include but are not restricted to drugs, cells and other biological products, surgical procedures, radiologic procedures, devices, behavioural treatments, process-of-care changes, preventive care, etc." (WHO, 2020).

In this context, population level interventions that involve government activity outside the health sector remain outside the scope. Policy defined interventions carry more authority and are more likely to be funded. Upstream interventions, such as taxation of negative externalities (such as sugar or junk food), or regulatory interventions that might seek to reduce exposures to harmful products, such as by regulation of toxic chemicals, bans on junk food advertising, and bans on junk food near schools remain outside the scope of consideration.

4. CONCLUSION

Exploration of the dominant terms and the definitions can reveal the logics which shape the policy environment to privilege particular forms of science production while marginalising or making invisible forms of science which might support the legal obligation of the state to protect health and prevent illness (PCO, 1956). First, the terms narrowly restrict innovation to a process (such as an intervention), or technological good (biomedical product) or service. Novel discovery as public good knowledge is a component of the innovation process. Secondly, an investment narrative assumes a tractable return on investment. This implies a degree of value or measurability. Third, norms relating to excellence can privilege research trajectories that fit dominant epistemologies, rather than encouraging new forms of science. Scientific excellence is discipline specific, and those outside a discipline find it difficult to judge excellence. Fourth, outcome is envisaged to be inside the health sector and a biomedical technology or intervention, or a behavioural intervention that is ultimately the responsibility of the individual. In this space, schemes seeking to address socio-economic health inequities that drive disease, and are outside the capabilities of the individual to remedy fall outside the scope for funding consideration.

There is little discussion of a broader biosocial model, which places the social determinants of health at its centre. The HRPF has gone some way to direct health research towards projects that reflect broader health needs. However, the HRPF contains little specific policy direction to look environmental determinants of disease, particularly when dominant policy instruments direct research to responsible and translatable investments.

Chapter 5 Public Health

1. INTRODUCTION

This chapter briefly discusses the developments, priorities and values that have underpinned the progress of public health and biomedicine. While public health and biomedical disciplines can overlap, they are solutions oriented in quite separate ways. “While public health claims to “focus upstream”—on ameliorating the social and environmental conditions producing disease—medicine is often assumed to look downstream, late in the process of pathogenesis” (Brandt & Gardner, 2000, p. 708).

The consequent framing, or scope that guides funding decision-making is a product of the epistemologies and consequent logics, values, beliefs and normative expectations, of the decision-makers that draft policies and funding frameworks. With this in mind, this chapter pays particular attention to neoliberal discourses around translation and innovation.

As anthropologist Marilyn Strathern (1997) noted, “things are formulated and conceptualized as a matter of practice or technique. People’s values are based in their ideas about the world” (p. 42). Therefore, albeit fleetingly, this chapter attempts to make sense of the epistemological backdrop of public health, medicine and biomedicine. As, following Strathern, “ideas always work in the context of other ideas, and contexts form semantic (cultural) domains that separate ideas as much as they connect them” (p. 42).

This discussion is an important cornerstone of my argument, as it provides an historic and culture-based lens with which to critically analyse the logics that perpetuate trajectories in health research funding. I show how the framing of policy both obscures the social and political conditions of disease production while supporting health-relevant activity inside the health sector.

2. ELEMENTS OF PUBLIC HEALTH

Public health has been described as ‘the art and science of preventing disease, prolonging life and promoting health through the organized efforts of society’ (Acheson, 1988) and more practically, ‘the organised local and global efforts to prevent death, disease and injury, and promote the health of populations’ (Beaglehole & Bonita, 1997).

Public health has always been political and multifactorial. Advocacy for change in human conditions is a necessarily political act involving decision-making between institutions and

networks around the production of knowledge, the allocation of resources and extent of regulation required to maintain population health. Scientific knowledge is a part of this process, providing information to policy makers that might support or restrict policy or regulation concerning inequality, workplace safety, education, housing, environmental chemicals, nutrition and pollution (McCartney, et al., 2019; Ottersen, et al., 2014; Reich, 2019; Sundin, 2019).

Historically, public health was occupied with the prevention and management of infectious disease at the population level (Rosen, 1958). Interventions in this context, were applied by authorities in order to prevent rather than cure disease and were often targeted to poorer communities. Infectious disease prevention focussed on community efforts to improve sanitation and personal hygiene; and improve housing, diet and drinking water quality. Authorities applied the tools of epidemiology, data collection and biostatistics to identify and then manage health threats via suites of interventions at the individual, community and population level (Institute of Medicine, 1988). The nineteenth century focus on infectious diseases largely united the public health and medical disciplines as practical and medical measures reduced morbidity from infectious disease (Rosen, 1958).

The relationship between public health and medicine shifted as non-communicable disease outpaced infectious disease as the primary cause of mortality. From the late nineteenth century onwards as medical knowledge concerning the pathogenesis of individual health conditions deepened, the medical discipline necessarily aggregated into narrower disciplinary fields and expertise became more pronounced (Proctor R. , 1991). Medical interventions increased following biomedical advances in the second half of the 20th century, including antibiotic and vaccination technologies, improved screening and diagnostics (Brandt & Gardner, 2000; Cohen, 2000; Rosen, 1958).

As medical training became more homogenous, public health education remained diversified, reflecting broader regional and disciplinary specialities. The potential for financial conflicts of interest exacerbated the uneasy tension between the public health and medical communities. Similarly, biomedicines' apolitical promise of solutions at the cellular level often contrasted deeply with the cumbersome, uncertain and ambiguous environment of public health. While public health continued to apply a broader social and environmental perspective, changes in medical knowledge and care had "uncoupled disease from its social roots" (Brandt & Gardner, 2000, p. 711). Biomedical development occurred alongside significant economic and geopolitical change. Neoliberal economic reform, public biomedical investment and private-public partnerships promising medical discovery were pitched as not only promising better health outcomes, but fiscally responsible (Schrecker & Bambra, 2015).

DRIVERS OF POPULATION HEALTH

Normative framing regarding the potential for medicine to protect health may be misleading. While biomedical research has made breakthroughs and individuals may benefit, delivery does not always translate into population health (Ostlin, et al., 2011). Baum (2019) maintains that the public benefits of biomedical research investment may be overstated: “estimates suggest that between 20% and 25% of improvement in population health can be attributed to medical intervention, and between 50% and 75% to social determinants” (p. 40). Health policies and resourcing have not adjusted to reflect the changing burden of non-communicable disease. The greater loss of functional health from non-communicable disease is under-recognised, with “low investment in research into underlying causes and therapeutic innovations for key causes of functional health loss is exacerbating this widespread and unacceptable neglect” (p. 1137).

Infectious disease pandemics have never been socially neutral. Socio-economic status has long been recognised as a driver of health and disease (Rosen, 1958). The 1918 Spanish influenza pandemic resulted in greater mortality and morbidity in working classes, and while Sars-Cov-2 has impacted lower socio-economic communities similarly (Bambra et al. 2020). Narratives placing infectious disease management inside an exclusive biomedical paradigm (Morens, Folkers, & Fauci, 2004) depoliticise the greater structural factors that often drive infectious disease, including poverty, population density, pollution, biodiversity loss and climate change (Schmeller, Courchamp, & Killeen, 2020). Environmental stress influences susceptibility and resistance to infectious disease (Casadevall & Pirofski, 2018). In the current environment the potential for EDCs to increase risk would be skeptically regarded (Nowak 2019).

Baker et al (2018) refer to a broad base of literature that suggests that the combined effect of neoliberalism, biomedical ideologies and culture, and pervasive racism has kept the social and structural determinants of health outside policy agendas. Their work emphasises the role of belief systems that thread through institutions, and in particular the role of ideological constraints, such as a medicalised culture, rather than strategic actions of powerful sectors. They assert a “medical dominance” perspective orientates policy and funding towards medical treatment rather than prevention (Baum, 2019).

Public health is complicated. Policy processes are often unsuitable for tackling complex non-linear problems such as the protection of health. The graduated production of health or disease over the life course contrasts deeply with short term election cycles. Problematics arise around translating knowledge into policy. The public generally accepts normative approaches of public health to

protect communities from infectious disease where there are interventions around individual liberty. However, this works differently for NCD where the links aren't quite as clear (MacKay & Quigley, 2018). Knowledge at the policy level is closely tied to the presence of expert communities, and the degree to which cause and effect relationships can be regulated is dependent on how uncertainty is approached (Bradford Hill, 1965/2015). Existing institutions and barriers can complicate decision-making, such as the financing and delivery of medical care and transnational factors such as trade agreements and regulatory actions that reduce nation-state autonomy (Exworthy, 2008). State policies can be maladaptive in times of disaster as institutional hegemony prevents common-sense ideas being debated (D'Alisa & Kallis, 2016). Similarly, path dependency can prevent timely institutional shifts (Greener, 2002).

TRANSLATION AND INNOVATION

The New Zealand Health Research Strategy (NZHRS) requires that research is translatable into clinical settings and recent health research literature reiterates this orientation (HRC, MBIE, MoH, 2019; NSC, 2019). At first glance, the concept of 'translation' is positive, it denotes a public good sensibility to guide funding – health research must be accountable. The NZHRS defines translation as "the process of turning observations in the laboratory, clinic and community into interventions that improve the health of individuals and the public – from diagnostics and therapeutics to medical procedures and behavioural changes" (MBIE & MoH, 2017, p. 42). However, the aetiology of 'translation' is biomedical in origin, rather than public health based. The concept was developed as biomedical research and technologies expanded to ensure biomedical research would be prioritised that was relevant and would provide beneficial clinical outcomes and improved health. The concept reflected the shift towards centralised and contestable funding models (Cohrs, et al., 2015) and emphasised responsibility of medical research investment (Murphy & Topel, 2003).

Translational research is firmly oriented to the biomedical. Translational research involves 'harnessing knowledge from basic sciences to produce new drugs, devices, and treatment options for patients' (Woolf, 2008, p. 211). In addition, a second slightly broader interpretation involves the translation of research into practice, ensuring the knowledge reaches the patient. Translation infers that new drugs, devices, and treatment will become available at the population level, and that knowledge around improved systems management and behavioural and educational interventions 'more informed choices' are implemented inside the health sector and within target communities (Woolf, 2008). Translational interventions are not positioned as leading to a political or regulatory intervention (Briggs, Wolstenholme, Blakely, & Scarborough, 2016).

Hence for scientist peers on funding panels, many who work in clinical settings or in biomedical research, 'translation' inside the health sector ensures research is feasible, accountable and transparent. But the concept places research that considers greater social and environmental determinants outside of funding scopes. Such framing may explain why the A Better Start National Science Challenge (NSC) was approved, while Gravida, which concerned the conditions of early life (Gravida, 2020) gradually lost funding. For the A Better Start NSC, translation is envisaged as occurring as behavioural interventions inside the health sector. At no stage are the social and environmental conditions that drive obesity discussed, including poor access to resources and the potential for endocrine disrupting chemicals to add to the obesity problem (NSC, 2019).

EPIDEMIOLOGY

The work of public health has normally been undertaken through epidemiological research to understand the incidence, distribution and patterns of disease in populations. Epidemiology and public health call attention to the political and social conditions of society, which are by nature dynamic, interconnected and uncertain.

After World War II epidemiological research transitioned to engage in the study of non-communicable disease. As with the medical field, over the 20th century the epidemiological field consolidated its base as a scientific discipline as statistical methodologies and quantitative technologies advanced. Lodged as it is between the public, government and industry, the discipline of epidemiology is methodologically cautious, requiring a supportive environment in order to flourish (Susser, 1985).

In the 1950s and 1960s the public health field pivoted away from its conventional focus on political and structural (macro) issues, such as income and environment to consider behavioural and lifestyle drivers of disease (Pearce, 1996). Epidemiological research exploring the cause of lung and heart disease drew attention to the role of smoking and diet, or 'lifestyle' factors in the development of disease. Prior to this, individual responsibility was not a recognised risk factor (Dew, 2012; Pearce, 1996). This new dominant epidemiological paradigm (Brown, et al., 2006) downplayed research into potentially controversial social and environmental causes and focused on behaviour.

As the Marmot Review (2010) noted, the 'lifestyle drift' of epidemiology may have been led by expediency, due to "the comparative ease of identifying action to address behaviour, rather than the complexity of addressing social inequalities shaping such behaviours" (p. 86). MacKay and Quigley (2018) argue that while behaviour is shaped by the surrounding environment, there has been a long-standing omission in research as neither the behavioural science policy, nor published

literature conventionally discuss the relationship between behaviour and the social determinants of health. This has produced blind-spots, where many of the policy reports in public health call for incremental, individual changes but ignores the social conditions driving behaviour (p. 383).

In contrast to lifestyle epidemiology, potentially ambiguous research engaging a social epidemiology (O'Campo & Dunn, 2012) approach, and exploring the upstream factors such as poverty, pollution or social stress has been difficult to justify.

AN EXCLUSIVE FOCUS ON HEALTH CARE

Health care inside the health sector misrepresents the extent of responsibility required to manage public health (Bambra et al. 2005). The Lancet now suggests that suggests that "an exclusive focus on health care is a mistake" (The Lancet, 2019). As Marmot has observed: "when health professionals contemplate inequalities in health, the default position is to consider inequalities in health care. Indeed, when international agencies speak of 'investing in health,' they actually mean: investing in health care" (Marmot, 2018, pp. 195-6). A health sector that ignores equity outside the health sector can exacerbate health inequities rather than drive them (MacKay & Quigley, 2018; Marmot, 2018).

Conventional modelling inside the health sector restricts the capability of decision-makers to value work outside the sector. Conventional cost-effectiveness analytics concern interventions inside the health sector (Daroudi et al. 2021). While this legacy may be a function of historical limitations around data quantification and modelling, this framing produces knowledge gaps regarding the weighting of upstream social determinants and environmental factors that drive disease, and related behavioural factors.

3. BIOMEDICINE: GENETIC AND MOLECULAR ASCENDANCY

Medical interventions have decreased population and individual, (or host) susceptibility to infectious disease, and in turn increased life expectancy (Cohen, 2000). Infectious disease prevention and genomic and medical advancement has propelled an important body of public health work to focus on biomedical development, delivery and services inside the health sector (Beaglehole & Bonita, 1997). Biomedical research encompasses "computer and information sciences as well as all the biosciences and technologies such as molecular biology, genetics, genomics, biotechnology, pharmacogenomics, nanotechnologies, and medical technologies including those of visualization" (Clarke & Shim, 2011, p. 177).

The NZHRS defines biomedical research as:

> research with the goal of understanding normal and abnormal human functioning, at the molecular, cellular, organ system and whole body levels. It includes developing tools and techniques to be applied for this purpose; and developing new therapies or devices that improve health or the quality of life of individuals, up to the point where they are tested on human subjects (MBIE & MoH, 2017, p. 38)

Although the two definitions are slightly different, both emphasise the interrelationship of human biology with medical technologies. While more commonly associated with disease prevention or mitigation at the individual level, biomedical interventions can apply at the population level, for example, for mammography screening and serum testing and diagnostics, vaccination and dental services.

The study of medicalization is the study of how a health condition or disease is recognised as medical rather than social, economic or environmental (Clarke & Shim, 2011; Conrad, 2005). Medicalized cultures have been recognised as an ideological constraint in shifting policy agendas to incorporate upstream factors (Baker, et al., 2018). In effect, the "biomedical paradigm reduced the amount of attention devoted to a wider range of social, behavioural, and environmental forces in the maintenance of health and the production of disease" (Brandt & Gardner, 2000). Much of the social licence for public investment in high-risk long term biomedical research originated from the tacit understanding that the consequent knowledge would be in the public interest (Krimsky, 2003). As Dew (2019) has pointed out medicine only deals with the symptoms of illness, which commonly arises from upstream social and cultural factors. From this perspective, society has a moral obligation to consider greater change beyond treatment.

Biomedical research fits neatly with national science policy and biomedical research is a successful cornerstone of New Zealand's scientific output (MBIE, 2018). Policy documents support and incentivise scientists to produce or invent a medical treatment or process that can be patented or licenced underpins research funding (HRC, MBIE, MoH, 2019; MBIE & MoH, 2017).

4. THE DETERMINANTS OF HEALTH

The social and environmental determinants of health (SEDH) arise through inequality and poverty in society and the capabilities of families to access food, health, education, housing and wellbeing (Friel, et al., 2012). The complex interlinkages between immune health, physical health and societal health have been recognised since the advent of public health (Rosen, 1958). The combined effect of stress occurring from exposures to both environmental and genetic factors, including psychological, behaviours and exposures, or allostatic load, determines the degree to which

individuals experience repeated stress responses (McEwan & Seeman, 1999). Poor diets and unhealthy and polluted living environments can make lower-socioeconomic groups and communities of colour more vulnerable to non-voluntary socio-biological stressors, which include EDCs (Ruiz et al. 2018).

POLLUTION

While agencies focus on tobacco, hypertension, unhealthy diet, physical inactivity, obesity and the harmful use of alcohol, pollution is neglected as a risk factor. Pollution is yet to be a recognised determinant of disease. Diet quality and air pollution are recognised drivers of NCD (GBD 2019 Viewpoint Collaborators, 2020) but pollution is yet to be formally recognised (Fuller, et al., 2018). This framing delimits the potential for public health professionals to address pollution in research policy as other factors can be claimed to be more urgent. Fuller et al. (2018) suggested many factors contribute to this gap. They proposed reasons for omission which include the long latency of pollution related NCDs, "a bias in the health policy community towards clinical interventions", media discourse that fails to reflect the enormity of pollution, and pushback from powerful interests and the consequent regulatory capture which prevents adequate control of pollution.

RACISM

Policies aimed at individual responsibility and behaviour change can exacerbate societal injustices (MacKay & Quigley, 2018). Forms of discrimination interact with social and economic status, and stress from pollution to create greater vulnerabilities in marginalised populations. Socioeconomic status, the confluence of education, economic and occupational status is a strong predictor for disease (Adler & Newman, 2002; Hill-Briggs, et al., 2021). Historically marginalised and lower socioeconomic groups are less able to avoid stressful events and environments, and traditionally they have had poorer health.

The NCD epidemic and infectious disease risk is disproportionately held by lower-socioeconomic groups and in New Zealand, Māori continue to have vastly poorer health outcomes. A 2003 Ministry of Health (Ajwani et al. 2003) paper cited decades of policy failure, however the differential health burden has not been alleviated in the decades since (MoH, 2018). New Zealand's health system aims to address the legacy of decades of discriminatory treatment of Māori, however equity policies emphasise change inside the health sector. Over the same period, international evidence damning health sector centric activity has accumulated (Baker, et al., 2018; Marmot, 2018; Ottersen, et al., 2014; Swinburn, et al., 2019).

OBESITY AS AN EXAMPLE

The obesity and diabetes epidemics are perhaps the most problematic indicator of the limitation of biomedical and behavioural research. Diabetes is disproportionately a condition of poverty. As the Ministry of Health have acknowledged for decades, the cause of death directly attributable to diabetes underestimates the greater contribution of diabetes to mortality statistics in general (Ajwani et al. 2003; MoH, 2018). New Zealand has the second highest rate of pre-obesity and obesity in the OECD for children (OECD, 2019) with multiple (multimorbid) health conditions are increasing in adult and paediatric populations. Māori and Pacifika are disproportionately burdened by ill health, with children particularly vulnerable (Ajwani et al. 2003; MoH, 2018). Multimorbid conditions are more common than single disease conditions (Millar et al. 2018), with social factors and inequality increasing multimorbidity risk (Russell et al. 2019). The problem is not linear, as the cost of multimorbidity is super-additive, with the highest healthcare cost arising from neurological and musculoskeletal diseases (Blakely et al. 2019).

EDCs are clearly implicated in the development of diabetes and obesity. Synthetic hormones that imitate human hormones contribute to the risk profile of both NCD and infectious disease. EDCs contribute a wide range of metabolic disorders, hormonally dependent cancers, reproductive disorders, neurodevelopmental disease and IQ loss, and metabolic disorders, and thyroid disorders associated with obesity (Demeneix & Slama, 2019; La Merrill, et al., 2019). This includes weight gain (Gupta, et al., 2020) and disruption of immune systems (Nowak, Jabłońska, & Ratajczak-Wrona, 2019).

4. CONCLUSION

Public health and the science that is engaged to build an evidence base, has a broader role informing the mechanics of upstream intervention stretching beyond sanitation, drinking water, anti-smoking and infectious disease prevention. Environmental and social justice are overlapping entities, and health and disease is fostered from the “norms, policies, and practices that arise from political interaction across all sectors that affect health” (Ottersen, et al., 2014, p. 630).

There is plenty of evidence that locally produced scientific knowledge can contribute both to domestic deliberation and to global discussion. This was recognised in the global effort to address the ozone hole and climate change. Shifting policy upstream and sideways requires long-term, multilateral effort and education beyond the health sector (Gauld et al. 2006; Gluckman 2018).

Part III. What the Scientists Say

Chapter 6. Analytical Chapter

Introduction

This chapter explores the funding experiences of 15 researchers in New Zealand and Australia. I have separated the analytical section into three parts. Part A explores participant perceptions of whether EDC research is an established field of endeavour in New Zealand. Part A investigates EDC field visibility, the presence of relevant laboratories, potential for knowledge diffusion via education and conferences. As most scientists were not actively engaged in EDC research, this section enabled me to gauge the degree of acceptance in the peer community. Their responses confirmed my observation that there is an absence of institutional presence of the EDC research field.

Part B and C analyse how governing processes for science production in health research frames out EDC research. I approached this by overlaying policy discourse with FP norms which I then contrasted with scientist experiences. This enabled me to examine the political and cultural frames of governing entities, - the institutions and FP's, with those of the governed, the scientists. Prior to the interviews I had identified dominant neoliberal and biomedical discourse in the policy literature, which appeared to establish terms of reference for what constituted a 'good funding proposal'.

For the participant scientists who participated in this research, the most critical factor enabling scientists to undertake research was the process of funding panels (FP's) ranking the research high enough in the list of proposals to be prioritised for funding.

Proposals were vulnerable to being downgraded prima facie where outcomes of research proposals were not conventionally biomedical and considered unlikely to result in a tractable intervention or application within the health sector. This was exacerbated by the scarcity of relevant schemes. While EDC researchers funding proposals exhibiting these characteristics were consistently downgraded, scientists in aligned fields could also be vulnerable to downgrading if their research demonstrated similar traits.

> Professor (B): you're required to be absolutely in that top 10% - sometimes in the top 5% to get over the line it means that anything where there is a level of risk involved in terms of the quality of the impact or the scale of impact, the outcomes or the type of publications that might result or other questions about feasibility impact get raised – it sort of puts it down the list.

> Research Associate (I): I think the trickiest part for us is funding. Ethics and other things – they're bureaucratic things – they don't prevent research from happening, … they can slow things down but certainly funding.

> Professor (E): If you measure the rate of funding success, if you use that as your metric, then that is a thousand times harder than anything else I do.

For scientists, demotion of a proposal down the funding applicant list constituted a denial of funding, which prevented projects from being pursued.

> Associate Professor (A): Apart from funding? It's mainly basically funding. It's very easy to put together experts and teams, but without the funding to pay their salaries. I don't think there's a lack of 'want' from people (…) but I think the chronic thing is just continual funding of *that* research team, it's what it always comes down to.

Prior to interviews with participants, I had identified content in the policy literature that produced paradoxes for EDC researchers. I had identified that health research policy emphasised that research outcomes should be innovative, targeted inside the health sector and that investment was an important term of reference. I suspected that EDC researchers regarded health protection and prevention differently from biomedical and clinical researchers. However, I was unclear how these economic and market-based norms were enacted at the funding level. I was also aware that cultural and social environments of FP's could reinforce existing power relations (Braun, 1998).

After interviews with scientist participants, I was able to associate governing literature (the policies) with the expectations and norms of FP's and the scientists who were successful in funding. Their framing was consistently and normatively biomedical. The strategic priorities of the New Zealand Health Research Strategy (NZHRS) align with biomedical research. The NZHRS text framing encourages the production of biomedical science. By framing I refer to the selection and transfer of information where communication is made more 'noticeable, meaningful and memorable' more salient, to the target audience. Framing processes operate through the use of culturally familiar symbols that resonate with the existing schemata in a receiver's belief system (Entman, 1993).

The interviews revealed that the autonomy of scientists was restricted by factors that, following Nader (1997), I propose, act as controlling processes. Controlling processes shape a matrix of decision-making for FP's that direct health research in the physical sciences towards biomedical

research and produce barriers for research that is outside the framing of the key policy terms.[ii] Controlling processes occur at a primary and secondary level.

		Funding Panel Approach	**EDC Research Approach**
[B]	**Key Terms**		
1	Innovation	Neoliberal/Biomedical: Innovation (OECD Oslo definition) products, services, processes or organisational methods inside health sector.	Environmental exposures & disease & disorder development (upstream). Innovation as a new process; novelty is emphasised
2	Translation	Biomedical: research results in diagnostics, technologies & drugs. Applied focus	Non-biomedical. Social and environmental determinants. More basic.
3	Equity	Equity – translatable outcomes (service & drug delivery) inside health sector	Socially produced drivers of disease – (Māori & Pasifika more at risk) apply outside health sector
[C]	**Logics**		
1	Single disease	Disciplinary – single determinant (allocate to primary disease).	Multidisciplinary (effects across biological systems)
2	Prevention	Primary prevention – Improving diagnosis and treatment of disease and injury. Research on, for the treatment of patients.	Primary & primordial prevention – prevents production of chronic disease & disorder (strong focus on DoHaD)
3	Excellence & Impact	Tracked through publication output, commercial applications. Benefits applied science	Does publication output improve health? Novel, multidisciplinary & slower publication output.
4	Contradictory	Endocrine medicine normal (exogenous substance)	Scientists struggle for recognition that an exogenous substance disrupts hormones
5	Investment	Reinforces innovation & translation – clear line of sight – directs to biomedical application	Incalculable, normatively long-term & expensive. A challenge for all non-applied researchers
6	Economy	Health research compliments the economy	Economic growth requires stewardship. Necessarily arms-length from industry.

[ii] I emphasise that this thesis concerns the implications for physical scientists rather than social scientists working in health research.

Part B discusses primary barriers which I refer to as key terms. Primary barriers are dominant and repeated terms that have been identified in policy discourse and emphasised by scientists. These key terms *innovation, translation* and *equity,* are repeatedly emphasised and clearly defined in policy (HRC, MBIE, MoH, 2019; MBIE & MoH, 2017; MBIE, 2015). The aggregate effect of these three terms shepherd physical scientists towards biomedical research. Scientists clearly understood the biomedical terminology. However, as an outsider, until I explored the aetiology of key terms I could not recognise the intent and weight of the overarching policies. As Entman (1993) had noted, framing utilises culturally familiar signalling. For those outside a culture, such communication can be difficult to recognise, interpret or remember.

Secondary level barriers, discussed in Part B, reinforce the key terms. Secondary level barriers are comprised of logics, or governing neoliberal and biomedical mentalities that direct science production towards applied and outcome-based solutions.

The terms and themes revealed multiple cultural contradistinctions between the characteristics of governing bodies, and the type of research scientists preferred to undertake. The consequence was a framing out or downgrading of research that was inconsistent with the operating definition of the key terms. While EDC research was frequently inconsistent, other forms of research could also be inconsistent. Scientists struggled for funding when their proposals deviated from the biomedical norms. Physical scientists researching the social and environmental determinants of health (SEDH) were generally outside the scope for funding.

Overlaid across the 3 key terms and the 6 logics which apply to all schemes applicable to physical scientists seeking to do health research, is the effect of a contestable funding environment. Hypercompetitive funding environments drive funding towards safe research choices (Laudel & Gläser, 2014; Moore et al. 2016). The funding programme that New Zealand scientists noted was most likely to support EDC research was the Health and Wellbeing research investment stream. This programme is heavily contested with around 12% of applicants receiving funding (HRC, 2020b). The contestable funding environment appeared to act as a ratchet, tightening the parameters and reducing the likelihood FP's would approve funding for risky, disruptive or unconventional research. Together, the governing discourse, the biomedical paradigm and the slim chance of being funded coordinated the behaviour (Dryzek 2008) of the health research community.

Acknowledging the small size of this project, I could identify how the key terms and logics not only placed EDC research, but other forms of science outside the funding scope. Scientists who did not adhere to biomedical norms could find themselves in liminal social spaces and unfunded. As the

scientists exhibited a considerable degree of knowledge and were articulate on these issues, this three-part analysis is structured to enable the scientists to provide a rich account of their experiences. The themes are overlapping, and I have attempted to clarify as much as possible the various issues, acknowledging that my classification is subjectively determined.

Part A. EDC Research as a Valid Scientific field: Field Visibility

This section explores the degree to which EDC research is recognised as a valid field of research, the degree of field visibility, and ways participants have gained knowledge of the presence of EDCs in environmental and human health. While exploratory searches prior to the interviews had been unable to identify functioning laboratories, or physical scientists who identified predominantly as EDC researchers, I required confirmation from participants to progress to answer my research question. If the field was established, and funding had been granted in the past my initial hypothesis would have been without substance.

1. EDCs & paradigm acceptance

When queried, EDC's were viewed as a health risk by all participants. All scientists accepted there was a plausible relationship between synthetic chemicals and disease burdens with the vast majority of scientists unequivocal that a relationship existed. When asked whether there was a research gap, twelve scientists, based in New Zealand and Australia confirmed there was a research gap. Three, working outside the field, stated that they didn't have enough evidence to answer.

Participants had not observed colleagues' express interest in pursuing EDC research. Responses were inconsistent when asked if the university and science community considered that EDCs contribute to chronic disease. Roughly half considered it was unlikely EDCs were considered a health problem. Comments ranged Professor (C) who stated 'No I don't. All the interactions I have would suggest that that really isn't the case', to more nuanced responses. Most reflected this perspective:

> Professor (B): most people would say that there is sufficient to raise the question of their contribution, but the science isn't yet settled on the degree to which that is important and … they would bet that it would be somewhere between a very subtle and a more profound impact.

Scientists acknowledged the normative tendency to focus on their own immediate field of expertise, "[t]he problem is that we all value our own area more than everybody else's". As Senior Researcher (F) explained about EDC risk "It's not high on people's agenda".

> Endocrinologist (L): I think people are vaguely aware, but I don't think they are probably aware of the importance – potential importance.
>
> Endocrinologist (N): sometimes I think it is … If people are bogged down in one little area of thyroid bloody vasculature or something – adrenal work or ovarian whatever – they might be a bit frightened of the area, they might feel as though it's going to be too hard to get funding for and they don't want to go into that area maybe...
>
> Professor (C): He's got a nice little niche carved out… Whereas if they started to incorporate our work, I'd be saying well let's do some molecular modelling and see if that can – "Oh I don't want to do that!" He publishes in the top journals and so on – so there's no need for him to do that.

2. Laboratory / Institutional void

Expert laboratories advance knowledge in their disciplinary sectors which can inform the public sector. Australian scientists, all with experience in EDC research could identify laboratories in Australia working in the field. No New Zealand scientist was aware of a dedicated laboratory in the human health field. Two New Zealand scientists suggested a toxicologist whose work has included research on environmental oestrogens, and supposed that work was being undertaken at the Research Centre for Hauora and Health, which conducts epidemiological studies researching exposure levels of environmental chemicals in the New Zealand population.

> Professor (M): The very fact that I can't point to any labs working on that in NZ at the moment.. I mean there are far more specialised and specific things that people are working on and getting funded to do so – perhaps to our shame that we don't have a big strong lab working in that area that I'm aware of.
>
> Professor (G): we are talking about low level exposures, things like toxic compounds, EDCs, persistent organic pollutants – we just don't do it very well and we haven't spent a lot of time improving our capacity.

None of the expert scientists had observed a shift to incorporate EDC research, outside their own laboratory. The New Zealand institute that had been proximate to this field was the Centre for Research Excellence, Gravida, which was tasked with researching the developmental origins of disease. Gravida was recently defunded.

> Professor (C): slowly (the centre got very multidisciplinary) the centre lost its funding. I could never quite understand why it lost its funding… And it may be because it was getting too broad and the government assessors couldn't see what it was producing because its output was much slower because of the breadth.

The laboratory void produced an additional barrier. There are no public analytical laboratories with capability to widely screen for environmental chemicals in human tissue and fluid samples in New Zealand. Scientific, medical and health practitioners must send samples offshore. This is a highly specialist area and the instrumentation is expensive.

> Associate Professor (D): 'it's not an easy field, and requires years and years of experience for commercial labs to set this up (…) If there is no real financial incentive (i.e. the new lab procedure is not likely to be used a lot or have commercial appeal), this is unlikely to be developed in NZ.'

Scientists sending samples overseas can be faced with confounding issues relating to storage and contamination that amplify uncertainties in study results.

Three scientists had suggested the Crown Research Institute ESR could play a role during their interviews. Human biological testing at ESR excludes environmental chemicals that harm health.

3. Toxicity: Ways of knowing

Absence of education regarding the toxicity of everyday chemicals can contribute to an acquiescence to toxicity, keeping research and regulation outside public agendas (Woodhouse & Howard, 2009). Scientists reported that EDC based knowledges were sought out or self-taught, and unlikely to be emphasised in tertiary curriculum, biomedical conferences or high-profile journals. All *expert* scientists had elected to learn about health risk from environmental chemicals in their tertiary studies either through their chosen course or via papers on the subject. *Aligned* scientists were more likely to have elected to learn about environmental chemicals than the *no expertise* and *some expertise* groups. Medical degree graduates had been exposed to toxicology, but with a focus on acute exposures as poisoning incidents rather than chronic low-level exposures.

Part B. Biomedical Conformity: Key Terms Embedded in Policy

1. Barrier: Innovation

The national science system is positioned as a national science and innovation system (MBIE, 2018) and the NZHRS refers to *innovation* around one hundred times. Science considered suitable for funding is required to be innovative. Innovation is clearly defined in policy "the implementation of a new or significantly improved product (good or service) or process, a new marketing method" (MBIE & MoH, 2017; OECD, 2005). New Zealand's policy position reflects the international literature which places innovation within an economic growth, technological development, and commercialisation frame. Scientists recognised the policy focus:

> Professor (O): I think the long-term goal of our work is to provide understanding of the mechanism of a disease so that a drug or a treatment could potentially manipulate that pathway and provide some sort of treatment.
>
> Associate Professor (A): I think people's idea of innovation is quite limited usually, especially in NZ. It's usually a product, it's an active treatment, it's a new process … they have a very defined narrow view of what innovation is.

I explored how scientists considered the term 'innovation' was expressed in research proposals. Three scientists defined innovation similarly to the NZHRS preferred OECD business definition. Ten of the scientists applied the traditional scientific definition of research and development – of a new or novel technique to advance a field. These scientists tended to place innovation in a similar category to novelty. Two were unsure. Scientists were more likely to emphasise the importance of advancing knowledge than producing a product, process or service.

> Professor (G): Usually innovation applies to notions about advancing a field, either by increasing our understanding of processes, usually biologic ones, but sometimes sociologic or epidemiologic by improving the way we can detect disease, possibly improving the way we can treat disease…Usually it's about prevention, early detection and treatment: can we move forward the field in which we are moving in a way that ultimately benefits the population?
>
> Senior Researcher (F): Innovation is not a word I hear very often in the circles. You hear that more in business circles, I think, than science. The word I hear is a novel aspect, it's a new way of looking at problems. They emphasise collaboration and multidisciplinary approaches.

Traditional scientific norms demanding that science should be novel, do marry well with EDC research. Novel findings commonly arise following earlier multidisciplinary endeavour (Fontana,

Iori, Montobbio, & Sinatra, 2020). Novelty, as a new knowledge combination, is valued epistemologically and commercially. However, novelty does not infer an innovative outcome. While the NZHRS considers that research and development can be novel, uncertain, creative, transferable, and reproducible (MBIE & MoH, 2017), innovation is a key directive term.

2. Barrier: Translation

The term *translation* is complimentary to innovation and discussion relating to innovation frequently lead to discussion on translation. I recognise translation as a controlling process that directs research to biomedical applications inside the health sector. In competitive environments, assurance that research would be directly translatable assisted FP's in ensuring their investment was responsible.

> Associate Professor (A): I get it, they've got a limited pot of money and if they're trying to look at intervention for pre-term babies (…) versus someone who wants to do a study on EDCs in a population, well they can see the direct translation and benefit (…) and intervention versus no intervention.

> Professor (B): I think funding bodies are interested in high-throughput analyses. They're interested in anything about environment – gene-environment interactions – where there might be genetic dispositions, I think that might fly. I think they're interested in where there is a commercial opportunity. If there's new chemical compounds that would have a clear value proposition and could be commercialised… They're very interested when there's existing industry or commercial partners. But when it comes to just demonstrating damage I don't know that they're that interested because what do you then do about it? They're not all that interested in the developmental origins of disease.

However, scientists considered it was important to have research that goes beyond development of biomedical applications was important.

> Professor (G): I will say I think we spend far less money on public health than we do on treatment. Public health as in prevention and understanding what's going on.

> Professor (O): My perspective on this is that the environment impacts on our biology, and if the environment is changing, we need to understand how that is affecting basic biological processes, and so they are absolutely compatible.

The key terms steered FP's towards funding applied research which resembles the outcome based framework of modern research environments (Bentley et al. 2015). A clinician acknowledged that it was easier to recognise applied research as translational:

> Endocrinologist (L): I guess one of the particular factors increasingly is the relevance to Māori and how it's going to reduce inequities – I think that is one of the big things. And it's also – some of it's the impact in terms of how is this going to make an impact? (…) as opposed to more esoteric research that isn't something that's obviously translational.
>
> Investigator: So is it easier for example if it's applied rather than basic or –
>
> Endocrinologist (L): Yes. It does - certainly seems it and certainly sitting on panels it does seem easier for ones that are more clinically relevant.

A professor of basic science described the process of downgrading of science:

> Professor (M): because it is so competitive but even though I submit my research grant application to one of the panels that's kind of the basic science panel it's called Health and … nevertheless all it takes is for them to put a couple of clinicians on an assessment team on that panel and word their application so that there's a considerable chunk of marks attached to the bit where you have to write in the application about how it links – how it could potentially link or how it will link through to clinical practice and making people's lives better and I might write some words about how it will build knowledge and that knowledge will be taken up by the next people along the track and that will turn - eventually translate into better health – but the two clinicians on the panel say I don't really buy that so they will score me low there and that will be enough to do me … I have to come up with some relevance or I'm doomed.
>
> Investigator: You've possibly observed this happen in the past?
> Professor (M): Oh yes. Yeah.

3. Barrier: Inadequate attention to Equity

Equity of care is critical, and New Zealand's healthcare system has a poor record for ensuring equity of health care (Came, 2014). While the social and structural determinants of health are mentioned in a later paper (HRC, MBIE, MoH, 2019), health research in the physical sciences remains predominantly directed towards biomedical and behavioural outcomes inside the health sector:

> Translating ideas and discoveries into diagnostics, prognostics, treatments and interventions with a direct impact on patient care and capturing the commercial value for New Zealand (HRC, MBIE, MoH, 2019, p. 9).

For many scientists, social justice and engagement addressing primary drivers of the burden of disease was a central issue. Environmental exposures can disproportionately affect poorer and marginalised groups (Prochaska, et al., 2014):

> Professor (G): I do worry that there is insufficient oversight in our funding bodies to ensure that certain areas of research where the health burden is highest, and the opportunity to make a difference with research and the scale of the knowledge gaps is particularly large

> Professor (B): Although I get very excited about molecular and cellular biology, I get even more excited about integrating science with politics and social questions and issues that prevent us learning or applying the knowledge that we generate in our research to making a better world and a better life for people.

> Senior Researcher (K): Some of the things that comes to mind is precision medicine (…) Innovative - but have you thought about ethical implications, have you thought about how it's going to - when you don't have an equal society this precision medicine is not going to work. It could actually discriminate people even further. Insurance, socio-economic class, whatever … people don't think about it.

> Professor (G): The findings tend to be consistent, and disease risk is higher in people we know are the most vulnerable, or the most exposed or living in the crappiest conditions or having the poorest incomes. So, all of that tells us that there is some collection of information around the multiple factors that we could be better tapping into. We sort of acknowledge it when we talk about equity, but we don't think it through in ways that allow us really to have that broad view.

Health protection and health prevention at population level (primordial and primary prevention) is not stressed as a primary purpose of the health strategy. "Protection" is considered in the context of "ensuring research contributes to equity for Māori health and wellbeing" (MoH & MBIE, 2019, p. 9). Policy does not address the SEDH, in particular the potential for a broad range of illnesses to have their origins in developmental stages. As Professor (G) noted, past improvements in chronic disease have been related to improved drug control of some chronic diseases (as opposed to improvements in obesity and exercise).

Unprompted, most scientists brought up the topic of obesity, which drives a wide range of multimorbid health conditions and disproportionately affects Māori and Pasifika (MoH, 2018). Scientists were keenly aware of disease relationships, such as obesity and cancer and the paradox in studying the aetiology of a single disease.

> Associate Professor (J): it's not just diabetes – it's everything that's associated with obesity – which is another dozen things. Obesity drives cancer and lung troubles and liver disease and cirrhosis (…) it's the key to so many things, so as the third or fourth most obese nation in the world – western world – you know I think it has to be a priority.
> Senior Researcher (K): women going through pregnancy with gestational diabetes, giving birth to children who are more prone to diabetes, who then will have kids who are more likely to .. you know? It becomes a vicious cycle.

> Associate Professor (A): Our public health approach is continually trying to refine things. But they're refining things based around the idea that these are lifestyle disorders (…) as opposed to (…) there's been an explosion of knowledge of how the brain controls bodyweight, how the brain deals with metabolic signals (…) So all of that is massive new biological knowledge, yet our public health response to the problem is still the same.

> Associate Professor (J): If you could cure obesity, you know, we wouldn't have a lot of the cancers that we have – right? And obesity is involved in a lot of the mental health and the neurodegeneration. So we absolutely need to understand it. And then if we can't cure it we need to try and do our best to prevent it. But there's so much we don't understand. And it's not all about exercise and diet.

Part C. Biomedical Conformity: Reinforcing Logics

1. Biomedical logics: Disciplinary or Multidisciplinary

EDC research is a "fundamentally multidisciplinary endeavour" (Schug, et al., 2016). However, throughout the interviews, EDC and *aligned* researchers cited many instances of multidisciplinary collaborative proposals that were turned down by FP's. This was underscored in interviews with scientists, who demonstrated a great deal of innovative disciplinary endeavour. EDC and aligned scientists described working with social scientists, gender researchers, mathematicians, epidemiologists and environmental chemists to develop new techniques. Scientists understood that a chemical exposure could drive obesity, inflammatory processes and infertility and that there were multiple novel ways these effects could be explored, analysed and discussed.

In contrast, biomedical research which can also be collaborative, conventionally focusses on collaboration around the genomic and biological patterning of a single disease. Cultural norms focussed on researching a single disease meant that broader, unorthodox approaches could be problematic.

> ‘the current system of scientific training that requires young scientists to burrow ever deeper into a single area of focus as they move from undergraduate work to master's level work to doctoral level work’ (Schug, et al., 2016, p. 12).

The potential for overlapping contexts and unfamiliar applications stretching across multiple disciplines without an innovative endpoint were likely to be confounding for peers.

> Professor (G): Most people who work in research have a fairly narrow focus, so they usually think about heart disease or they think about hypertension or they think about breast cancer or they might think about infectious diseases, again, usually, limited. Most people don’t think about multiple endpoints, even when they think about multiple exposures. It’s not how we are trained.
>
> Associate Professor (A): … the disciplines historically have had very siloed approaches and when you get a very broad ranging question across multidisciplines it is a little bit harder to get going, and also harder to get funding or publish and that’s sort of preventing people from getting [traction].
>
> Professor (G): The general position is: if I can measure something easily, I’m going to study it. Hopefully I’m thinking it’s related to an important outcome but if I can measure something easily, like somebody’s smoking habits, rather than their exposure to some particular low-level chemical, that’s where I am going to go, because it’s easier.

One scientist described a mentor who said:

> Professor (C): Don’t get narrow, it’s no good knowing more and more and more about less and less and less. You’ve got to get broader and broader and broader.

I had been surprised when relatively few endocrinologists joined as participants. I had presumed interviews with endocrinologists would play a large role in this research project. Only five participants in the participant field identified as endocrinologists, and of these, only one had experience in endocrine disruption. When this disciplinary deficit was mentioned to a participant they proposed:

> Associate Professor (A): I think a lot of pure endocrinologists don't necessarily worry about what's causing the diseases that they study, or the molecular footprint for them, they're just worried about elucidating what the mechanisms are of that pathway. So they're not quite as focused on that. The ones that are, do find it hard to get funding, I think, so there are probably more people who are interested in it but can't successfully get a pot of money towards it because it's so nebulous (…) I guess endocrinology is a very specific term (…) but they tend to focus on an organ, or a system within an organ, or how that organ works. They don't often worry about the environmental impacts on that organ.

This suggests that endocrinologists on FP's were more likely to have an applied focus. Therefore, even though their disciplines were associated, the unorthodox approach of EDC researchers considering multiple categories of disease was likely to be unfamiliar. This reiterated Bourdreau et al.'s (2016) finding that unorthodox science was particularly at risk of rejection by disciplinary colleagues. In contrast, EDC researchers normatively navigated between immunological, endocrinological, inflammatory, metabolic and developmental parameters across disciplines. For example:

> Professor (B): In neurodevelopmental disorders like autism and mental health, metabolic disorders that result in childhood obesity, but then later in life, diabetes, and heart disease, and stroke, and the immune system disorders with the increased incidence of auto-immune diseases, allergy and asthma – all of them can be caused by inflammatory signals coming through the placenta. And depending on the balance of those signals and the tissues that they target in the foetus you get different consequences. They can be quite subtle and quite difficult to measure and find but then become more evident as the infant grows older and they manifest in these different ways. We think the EDCs are influencing that whole pathway.

Multidisciplinary collaboration adds considerable complexity to research proposals and multidisciplinary research is more difficult to sustain (Maglaughlin & Sonnenwald, 2005). Multidisciplinary collaboration across basic disciplines is rare (van Rijnsoever & Hessels, 2010). Conversations with the scientists suggested that disciplinary and biomedical orientation might not only limit FP members capacity to confidently identify external reviewers, but also make judgements around complex causal pathways and advocate for EDC related research.

> Associate Professor (A): it's about how open minded some of the panellists are to that type of research so that's probably the biggest hindrance. Often though, sometimes it's not their

> fault, they're given a specific remit … the newer multidisciplinary areas suddenly are not in that because it's a bit muddy so they'd rather fund something that was completely in scope, … so I think you get a lot of caught in between action, and so there's nothing physically there.

> Professor (H): They have different calls and for the most part a lot of them don't apply to the work I do so I ignore them [adding] the research that I am doing doesn't fit into the medical world view. So, the medical world view is that you manipulate one variable at a time or one molecule at a time. We're used to seeing things in the context of "we're going to give this group of people this one drug, this one entity". We have characterised it very well. We know where it works, we know its mechanism of action and we want to see whether or not it has any effect on any specific symptoms or disease states or whatever.

A professor described the inclination to drill down into an applied area of expertise rather than look more broadly, which limited the capacity for these scientists to research the broader systemic effects.

> Professor (C): I think what we've got to do, and we're not doing this – the grants awarding bodies, the journals, and everything – is to see this multi-faceted approach. Because currently we've got a scientist whose a great expert in some tiny little thing on the side of a cell, then you've got another scientist doing something on another cell with something different - and ne'er the twain meet. They're probably all looking at the same impacts, the same effects and the same disease, but for different reasons. And it's so bloody complicated – disease. And the point you're making about environmental – EDCs having an effect on the immune response – if we get increases in EDCs we get changes in sperm count and breast cancer, but we also probably get a bit of immune change, which might then lead to susceptibility to other diseases, which is rarely brought into the picture. We shouldn't be ashamed to say 'oh my god this is complicated'. Rather than try and dissect it out into simple little bite sized chunks, and then study them in isolation – because we don't see the big Venn diagram of the whole lot mixed together.

> Professor (O): The endocrine system is like the nervous system, it's the way our cells talk to each other, and you can't do it in isolation. The body is talking to the brain, the brain is talking to the body and one of the major systems it uses is the endocrine system and so it really has to be studied at a whole organism level, and obviously if you're interested in the

> brain there's not a lot you can do in a human model because the manipulations are really too invasive for that.

2. Logics: Biomedical Prevention versus Primordial Prevention

Scientists were questioned as to whether the health research funding prioritises prevention-oriented research. Scientists did not consider prevention was prioritised, however they considered prevention alongside a suite of favourable outcomes, or another box to tick.

> Associate Professor (D): If you can show that through that research disease can be prevented, and if you can show that it actually will have a financial implication for the health sector. All that does count, definitely. I wouldn't say it gets prioritised but it is just an additional point you can make in your application.

The most favourable comment was 'yes I would hope so' to a more frustrated 'No, no. Absolutely not. All of our stuff has been prevention orientated and they've turned them all down'. One participant clarified that preventative biomedical health interventions including screening for detection and treatment could be undertaken inside the health sector; and that research and policy could be applied to prevent the disease.

> Professor (G): Are things like primary prevention and early detection kind of bundled together? Well, they are because both of them reduce the impact of disease. One by stopping it entirely and the other by detecting it early and reducing its nasty consequences. We need them both. But you are probably right, people don't stop to think about what the real difference is between eliminating some exposure completely versus dealing with the consequences (…) people do not have a clear distinction in their heads between primordial prevention, primary prevention (…) I think we need them all. We have probably neglected the first steps most of all…

When prompted further about primordial prevention:

> Professor (G): If you're thinking about developmental origins you're thinking about long term consequences of heart disease or mental health, from early childhood experiences (…). Yes, that's primordial prevention because that's preventing the kinds of exposures that matter, long before you'd think about the downstream consequences: when you reach the age of adolescence, or adulthood, or even late adulthood. We've got good evidence that those early exposures and experiences actually matter.

Biomedical approaches to prevention could be interpreted as innovative while primordial prevention interpretations could be conceived as problematic and uncertain. A professor researching the cumulative risk of exposure to the class of oestrogenic compound (which can be natural and synthetic) with implications for individual and population level intervention described the dilemmas faced by FP's and researchers:

> Professor (C): Yes, I've been turned down so many times I've given up actually, now. The reason I'm turned down is a legitimate one. That is, the HRC like research that is going to directly affect patients or be very patient oriented [Investigator: Have direct clinical application?] Yes. So what we're normally doing, and the last grant we put in was along the lines of, we're looking to try and minimise the development of breast cancer by trying to change women's diets or at least letting people know that there are compounds in the diet that could promote breast cancer so if we could actually prove that then it might be a way of reducing breast cancer. But that isn't their remit really. And it's very often not the remit of anybody – you've either got to develop a new drug or you've got enough drugs for breast cancer that don't work, we don't want any more. So most people are being pushed down a road because the grant awarding bodies want you down there to develop new drugs. You know we put a hydroxyl group in a different position – Yay!!! – you'll get a grant for that.

Governing institutions require scientists with independent autonomy to research knowledge gaps and verify industry claims, as without independent stewardship by the state, there is risk of market failure (Michaels, 2020). The above example highlighted an important issue, regulators are not considering risk from total exposures from a single chemical class. This study was hoping to step into this gap, however, it could not secure funding. When scientists were questioned how innovation could compliment prevention-oriented research their focus shifted to primordial prevention, rather than prevention in the health sector:

> Professor (H): Can it be as simple as thinking about… prevention is – is that we're trying to stop a disease state from developing in the first place?
>
> Professor (G): that's partly why I separated off the notion of equity from innovation. They usually are perceived as being separate issues. You are properly asking the question – is that a legitimate separation? Have we got a better way of improving equity? Is that not in and of itself innovation? I think the answer to that is yes, but I don't think that is a general perception.

One scientist referred to the focus on commercial development and the inherent conflict in a science system that has historically emphasised innovation as a primary driver of health research:

> Professor (E): It doesn't because prevention rarely results in intellectual property rights that can be licensed by someone who has an interest in doing so because they can sell the prevention. The exception to that is when you define something like a vaccine as a preventative.

3. Logics: Excellence & Impact

New Zealand's national science system rests on foundations of excellence and impact. While the Health Research Council recently adopted a broader interpretation of impact (HRC, 2019) in the broader governance sphere, publication output and citation impact are recognised metrics for scientific excellence (MBIE, 2015; MBIE, 2018).

A focus on excellence produce barriers to unorthodox science which is unlikely to be published in the top journals which as Professor (B) stated, are "not the places where you would expect to see that work. It's still seen as a bit fringe and a bit hard to pin down". Excellence cannot signify whether science will, for example, improve public health. In competitive funding environments where the science presented is "methodologically sound and scientifically robust", it is not unexpected that funding panels will resort to the quality of the investigators' C.V. – their publication output and citation impact. Scientists working in novel areas, using novel interdisciplinary approaches and technologies may not have the C.V. of competitor scientists who follow conventional research paths. Their work may not reflect the "line of sight" or translation emphasis that applied researchers might more easily comply with.

The state has acknowledged the importance of longer-term funding and flexibility for Crown Research Institutes (MBIE, 2016), yet public health research funding remains precarious and short term:

> Professor (O): We of course work in a system where we have grants that last for 3 years, and you're asked, what are you going to achieve in that 3 years. Our system is inherently short sighted and therefore, I think, is destined to not produce major breakthroughs. [Adding later] The productivity that we're getting right now is based on things that we started 15 years ago.

Many of the scientists considered that local activities or being published in second-tier public health journals were more important. Professor (E) equated impact as uptake by citizenry or government,

and invitations to speak as a personal measure of impact. In addition, finding an appropriately rated journal be more difficult, but locating reviewers who could engage with the multidisciplinary approaches could pose challenges.

> Associate Professor (A): you get caught between disciplines. That makes it very hard to find appropriate reviewers and – yeah – just to get published. So you have to be a little more persistent. Which is (shakes head) – and there aren't really journals that are right in the middle, they're sort of hard – so…

Another participant, a highly cited professor, described the difficulty of securing referees for papers. As publication output has escalated a disproportionately small group of scientists carry the burden of peer review. This dearth of available reviewers may apply also to reviewers of grants (Porcher 2016), Concern was expressed this issue may carry over into funding proposals:

> Professor (C): The same might be happening in grant awarding bodies. We don't know who has been given our grant to review it. It might be someone that just totally disagrees with the way that we are doing things. It might not be a justified disagreement. You just don't know. I mean I review and referee grants. You automatically look at these things 'well that's stupid they're not doing that like we are right' and you sort of have that feeling. You've got to keep pulling yourself back and it depends who is doing it, whether they pull themselves back enough or whether they might be making a judgement that's rather more personal I don't know.

The tendency to defer to the publication history to guide decision-making in competitive environments was recognised to unfairly disadvantage lower status scientists.

> Professor (O): [W]hat loses out in a system like we have are the young, innovative, new people who've seen the bright new ideas, because they're risky. How do I know your bright new idea is valuable – you don't have a track record because you are new, and I don't really understand the field because it is not my field, but I'm judging it, I kind of have to rely on the C.V.s.. So you end up that the funding tends to follow the senior people, and I don't think that is necessarily the most responsive way to go.

4. Logics: Investment & a clear line of sight

An entity that undertakes an 'investment' normatively assumes a return on investment within a defined period of time. Investment narratives dovetail with policy emphasising that science should be innovative and translational (MBIE & MoH, 2017). For physical scientists, the policy

frameworks unilaterally direct the 'clear line of sight' (MBIE, 2019a) towards accountable biomedical outcomes inside the health sector. An *aligned* scientist explained the problem of working outside the biomedical paradigm:

> Professor (H): I want to study them in combination (…) So, when you put that forward and you explain that they can still really struggle to understand that there are – they still want to know, well which is the special [compound] after you've explained there is no special [compound]. That means you are always going to be scored lower and having sat on panels that assess research, if there's any kind of query around the mechanism – the science behind the idea, you tend to score lower and not get money. So that's probably what happens to me. [Investigator: So, if there's any kind of uncertainty there] Oh yes, they're so conservative. And the funding (…) when you have a very small pot of money in a country like New Zealand, you are always going to fund stuff that is safe.

Non- EDC researchers could easily articulate the challenges for EDC researchers that created barriers to funding, and the uncertainty that made investment, particularly in the short term difficult:

> Professor (E): there's a sort of a list of obstacles. One is money because these are going to be expensive studies. It's going to be extremely difficult to go from epidemiological down to causative molecular level; and requires a huge diversity of people in order to achieve those transitions.

> Professor (O): I think what you've described at the end there is maybe one of the problems: chronic exposures. Having good experimental models of chronic exposure – these are very long-term experiments. You need the right experimental model. Is a rodent that has a 2-year life span a good model of a chronic exposure? So, I think those are the sort of questions… It's a little bit like ageing research.'

> Professor (M): the basic science is really needed in a controlled setting because it's so hard to – because every single person is exposed to compounds that are found in plastics and so on and so you're not going to be able to do really tight research in human populations – it's going to have to be in a controlled laboratory environment to get some science. And then maybe you can take the links out into the population.

> Research Associate (I): to me I guess, the biggest hurdle that you face, to get to a stage where you're going to work in humans is actually getting that basic understanding to a point where you can actually move into a human setting, so if you are looking at a clinical setting,

> obviously you need to have really strong knowledge of the biological pathways from studies in animal models largely, but you can do it invitro in humans as well which have that downstream – let's say it was on an EDC influence – so you know what is being influenced and what is changing, whether it be in the male or the female, and then also ultimately what you'd be aimed at looking at would be ways to prevent or treat that from happening. That basic knowledge for me is the biggest – it's not a hurdle but it's the most important part you really need to surpass to get to that point.
>
> Professor (O): the pathway is different, and we're being scored on that and so the question is how do you score: "I'm going to test a new drug that might cure cancer" to – "I'm going to try to understand about how biology works"? If they're scored on the same scale it's very difficult to understand how that's going to work, so that's a problem.

Scientists normatively accepted that commercial outcomes from research, while not necessary, were favourably regarded by FP's. When asked whether scientists that prioritise commercial outcomes possibly have easier access to money than scientists prioritising human health prevention, a professor responded:

> Professor (E): There's no question that it's easier …you're going to have an easier time. There's far more granting opportunities, there's far more government interactions you can have, and that is – since the government is the major funder of semi-targeted and untargeted money.

Investment narratives divert attention away from the long-term practicalities of maintaining laboratories and skilled staff. When questioned, laboratory heads considered that about 20 percent of their time was expended crafting funding proposals. Researchers in EDC or *aligned* and often non-commercial research areas were more likely to report they had given up or rarely applied for funding. Basic scientists with funding, spent their time worrying about when the next funding contract would come from.

> Professor (M): It's really three salaries that keep me awake at night.
> Professor (O): Science is facing a massive crisis in the lack of security of funding for our staff. So many of our scientists are on short term, fixed term contracts, and the universities are saying, well you know, that's great, 'we'll just let those contracts lapse and we won't renew them'. I think it's actually shocking how we've allowed a system to evolve where we're expecting these highly trained people to make careers out of 3-year contracts – or shorter – 3 year contract is good, if you get a 3 year contract, that's the best you can get –

> and still expect them to be there when some emergency comes up, like Covid. You wouldn't do that to a librarian, you wouldn't do that to a school-teacher, you wouldn't do it to a secretary, your wouldn't do it to a butcher. There's no other field where we would treat our staff so poorly as science. [Adding later] sort of the whole the more-market economy driven approach, really is about taking the here and now, and not planning for the long-term future.

When discussing innovation, one resigned researcher noted:

> Probably until recently they were funding middle aged white males would be my guess, and people over and over and over again. I've been thinking about people who have gotten HRC – they tend to fit into that mould, but maybe I'm being unfair.

One scientist drew attention to the potential for a small number of well-funded lead investigators to drive the direction of science in New Zealand as they are the dominant recipients of funding:

> Professor (E): Whereas right now, we mainly have a small number of people, who have about a 100% of the research flexibility in this country and they are determining the behaviour of everybody else.

New Zealand EDC researchers had lost funding to operate animal laboratories. In unfunded environments 2 New Zealand EDC researchers had shifted away from expensive rodent models, replacing this with molecular modelling or virtual laboratories. Molecular modelling is viewed as innovative and scientifically robust. However, while useful in theoretical applications, modelling technologies can exclude real life effects that in vivo mammalian studies provide.

5. Logics: Contradictory Skepticism Concerning Exogenous Exposures

Peer communities on FP's appeared likely to regard EDC research skeptically. Participants considered that FP's struggled to see EDC research as tangible priority alongside other causal factors

> Associate Professor (A): EDC research is highly polarising withing fields – you have your believers and non-believers, so often this skews the ability to evaluate grants/papers before they even read them.

> Professor (B): You're a bit on the fringe edge of things if you believe this stuff. I think even still there is a lot of peer pressure to not work in this area in Australia because people don't see it as a priority.

> Professor (G): It's a scary idea because if you don't know an area well enough, and it doesn't sound entirely plausible to you, then maybe you think these people are just crazy.

EDC researchers felt that FP's were challenged by the uncertainties, that the EDC researchers themselves were able to navigate:

> Associate Professor (A): They appreciate it, but not to the significance that it's on a level par with smoking, or alcoholism or a major factor that they know causes disease. We know that smoking hits many different diseases, but if I went to the cancer council and asked for funding, they'd be like, 'great, yeah we know that, it's dogma, we'll absolutely give you money to look at how nicotine affects certain receptors' whereas if I go and say 'I'm working in EDCs and cancer' they're like {reluctant/disinterested face] nah / yeah… maybe there's some data on it but you know there's not really hard core epidemiological data, and you know it's still a very contentious issue' – it's polarising.

> Associate Professor (D): 'they find health effects also for very low exposures. So it's very complex to study this. Even if you can find the population which is highly exposed, it may not even be the population you're most interested in, because health risks have been associated with very low exposures so it's, yeah, very complicated.

> Professor (B): To not consider this as the single cause and effect endpoint measure but as one of several that integrate together to have an influence. To use sophisticated modelling and statistical analyses to engage the extent to which it's a factor in relation to other causal drivers. How it interacts with things like smoking and nutritional exposures and obesity etc

There is a chance this may be slowly shifting. When discussing whether EDCs are a health risk, an endocrinologist responded:

> Endocrinologist (N): I think if you asked that 2 years ago I think the answer would be no. But as endocrinologists we go to these meetings or used to go overseas to these meetings. I think it's in our faces now. And our clinical journals which we all read and keep up with, there is something on endocrine disrupting chemicals probably once every three months or something…it's slowly heading there.

The fact that scientific peers might be skeptical about the potential for exogenous chemicals to impact endocrine function to a degree that causes harm is something of a paradox. This deserves some attention. An enormous range of biomedical innovation focusses on the development of drugs which interfere with hormone action, such as by binding to receptors or altering natural hormone

levels and receptor function. Signalling molecules, substances known as ligands, target and bind to macromolecules or receptors. Receptors then bind to DNA and regulate gene function (known as transcription). The operational model of drug action is "is based on experimentally observed relationships between receptor occupancy by a ligand and the production of pharmacological response" (Kenakin, 2009, p. 66). This method is the 'the preeminent method of quantifying relative efficacy in experimental systems'(Ibid). In effect pharmaceutical drugs operate by altering the function of receptors. Drugs are commonly administered to alter the natural hormone levels.

> Another vast therapeutic application of drugs involves the use of one molecule to interfere or otherwise modify the effects of another molecule that produces a cellular effect (the latter usually being a naturally occurring agonist such as a hormone or neurotransmitter) (Kenakin, 2009, p. 68).

Therefore, ligands can be endogenous hormones or neurotransmitters naturally produced by the body, or exogenous substances that mimic, interfere with or disrupt endocrine function. A ligand can be a drug *or* an unwanted endocrine disruptor. For example, just as scientists can target nuclear receptors to identify suitable drugs (or ligands) with binding potential (Zhao et al. 2019) nuclear receptors are vulnerable to binding to EDCs (Hunt et al. 2017). The difference is that drugs are (theoretically) controlled, while EDCs are a non-voluntary exposure. Many drugs are developed with the intention that they will be administered at a level a receptor recognises, and that the drug will be present for a suitable length of time in order for the physiological response to occur. Drugs can also act unfavourably as endocrine disruptors, either as an adverse reaction (Ferrari, et al., 2019) or through non-voluntary exposures in drinking water systems.

As I hope I have explained, low-dose, hormone level science is typically incorporated in medicine. Yet contradictorily EDC researchers found that their proposals were regarded skeptically. Absence of a supportive institutional presence could be a factor shaping FP reluctance to fund EDC research, and reinforce notions that the field is of low priority for funding.

6. Research for Growth or Research to Explore the Antinomies of Growth?

Scientists argue that the reason why health policy has been unsuccessful at addressing the SEDH is because of prevailing market oriented and biomedical logics that permeate policy and prevent political action (Baker, et al., 2018; Plamondon, et al. 2020). *Aligned* and EDC researchers considered that there were barriers to scientific research that potentially contradicted economic growth narratives or challenged existing institutional norms:

> Professor C: ‘if your work ‘has implications for the economy of NZ, particularly agricultural economy, and it’s negative – you really don’t stand chance of being funded.’
>
> Associate Professor (D): We seem to think because it is of economic interest to use pesticides, that means we should be ignoring the health effects, possibly. We’re not interested in it because it is so important for our industry? So important for our exports? I don’t know. That’s just guessing I guess. New Zealand is not at all progressive in terms of pesticides use. If you compare it to other countries in Europe, they have programs in place to reduce pesticide use, and they have reduced use by enormous amounts. There is nothing like that in New Zealand….. Is it really an economic thing that, just, the money speaks and health doesn’t?’
>
> Professor (B): There’s an enormous research gap. I’m sure, as we said right at the beginning, that we know there are chemical companies that are pressuring – find ways to apply pressure to push against that… we know from colleagues in the U.S. that that can become quite an aggressive push.

A scientist drew attention to the priority of ensuring key export markets were protected:

> Professor (C): if China decided tomorrow, that in order to import milk from NZ and we had to prove it didn’t have any [EDC] in, the research in NZ on [EDC] would get funded. It would go up. It would be unbelievable. The driver might be from outside whereas, internally, why fund that? This is just going to cause us another problem! We don’t need another regulatory headache thank you very much indeed… you can see why there wouldn’t be a government driver to try and fund that.

Adding later in the interview:

> Professor (C): we’re very interested in value added. We’re not interested in value deducting. So research that adds value, like a nicer golder kiwifruit that tastes sweeter – that’s where the research money is…. It’s not in selling another problem.

Scientists recognised that exposome research needed to be conducted at arms-length from industry interests. Research institutions in New Zealand are encouraged to establish private public partnerships, however this was not possible for EDC research which has potential to draw attention to harm from commercial activity.

> Senior Researcher (F) I don't know if we have a policy but we never take private sector money. We would compromise ourselves very quickly.
>
> Professor (B): We did talk about whether it would be good or not to bring in end-users and especially the industry, to get them around the table from the beginning. We decided not to in the end, because we thought the risk was just too high, although we will often work with stakeholders right from the beginning. But we obviously wanted to completely remove the conflict of interest question. I think that is really important. You know, what we've learnt from cigarette smoke and other areas – alcohol, is that you've got to not have the industry money involved.

When asked if social skill was related to securing large grants, a scientist replied:

> Professor (E): only on the margins Because social skill is not your ideological belief …. that research has to be taken up, and used, primarily by financial interests in a private sector then it doesn't matter what your social skills are, you'll get further up the ladder than if you are the nicest guy in the world and don't think that.'

Australian EDC scientists operating laboratories considered that the future of their laboratories were to a degree precarious due to the difficulty in securing funding. For all aligned and EDC researchers, funding was precarious, and EDC and aligned scientists described years of receiving funding rejections from the primary funding bodies. Barriers to funding meant that there were many projects that could not be undertaken and that the scientist's autonomy was substantially reduced.

In this environment, and with most institutes securing income from private and public sources, scientists working in sectors that drew attention to negative externalities of production could find themselves isolated. New Zealand scientists ended up financing their research from a scant university allowance, depending on a restrictive PhD stipend, and repurposing income. When a professor was congratulated for the work that was being done, they responded:

> Professor (C): Yep. It's very difficult to get funding though [Investigator: that's interesting]. Nearly impossible.
>
> Investigator: Where is the funding for the [compound] study coming from?
>
> Professor (C): I'm funding that from my university money. I'm given a small amount of money for each PhD student and so we're funding it through that. We've applied for lots of grants and they've all been turned down.

The most active laboratory, which was in Australia extensively relied on repurposed finances from commercial consulting. However, this was unusual. Repurposing commercial income is a common strategy for basic scientists, however it is dependent on the scientist being able to either secure a large grant or commercialise their work without conflicts of interest:

> Professor (M): I would say that if you asked all of those individuals – say 'why are you doing it' – one of the main reasons to do it is so that they can fund their lab and their staff, and enable them to carry on with the basic science that they are interested in, as well as addressing these commercial questions…

> Associate Professor (J): for many years that was very helpful, to get commercial money. But I've had to run all that money down to zero. Into the red, basically. I'm at the stage where I'm thinking you know, should I just put some of my own money in here, just to keep me going? Yeah. It's hard.

When asked about the importance of a PhD stipend, another scientist confirmed how important this was, however in this case, it was $2000, not enough to maintain a laboratory. The tendency for the well-resourced laboratories to attract the best students away from unfunded researchers was also raised.

> Associate Professor (J): it is extremely competitive, and there are a lot of things that go on that shouldn't go on. So yes it is all about the funding and how much money you can bring in and how many students you can have, because they bring in your money. So there's a lot of things which I do not like and I think most people wouldn't like that go on.

> Endocrinologist (N): It's what's sexy, what's in at the moment and I think it's just hard. It's probably just hard epidemiological and clinical research. It's basic science to start with isn't it that is always difficult to get funding for – it's always easier to get funding on human research I think. Because it seems more relevant to people and it's pretty hard to get rat research money… But I think it's going to grow a bit like everything as we start to realise our planet is entirely dependent on what we expose it to at the moment.

A few scientists discussed the social and political character of funding agencies:

> Associate Professor (J): the funding agencies are not randomly distributed and they have objectives and they have agendas when they issue grants….. Because it's still a human thing. Even what a panel decides is applied and is not applied, which can be the magic difference between funded or not funded, is an ideological sometimes, distinction.

> Professor (G): Those of us who have also been reviewers, understand the way this system works. It's horribly imperfect; it's just better than anything else. Its general shape is the right one: the peer review system is the right way to go. The trouble is you don't always get the right peers, and then you don't always get the best decisions. But it's hard to know what else to do.

Discussion

A combination of economic, political and cultural factors prevents EDC research being undertaken. The interviews with scientists enabled me to consider how state policies and biomedical culture interact to produce funding environments which privilege biomedical outcomes while displacing non-biomedical research. I identified key policy terms and corresponding logics which I propose act as controlling processes, guiding FP's and scientists towards particular funding outcomes.

While I had identified that neoliberal norms of economic growth and productivity had underpinned policy development, I had not understood how this impacted scientists 'on the ground'. This project was an opportunity to consider potential associations between policy, normative disciplinary frameworks and scientists experiences. I was aware literature exploring the relationship between policy and the production of scientific knowledge was relatively scarce (Gläser & Laudel 2016) and that the approach of this research project would be relatively novel.

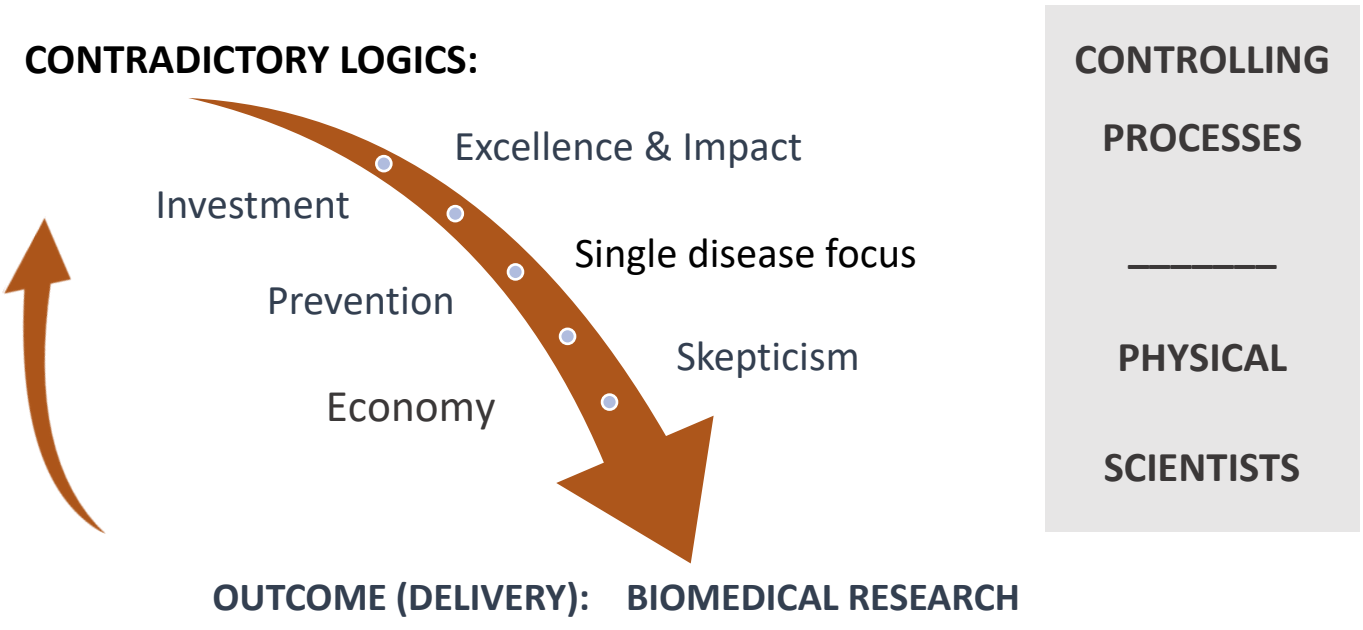
Firstly, I identified the key terms innovation, translation and equity, which thread through the policy literature, and I secondly, theorise that key logics reinforce and embed the terms. I identified biomedical researchers and normatively aligned panel-members; to have distinctly divergent logics from EDC and non-biomedical researchers. Logics are contradictory or diverging systems of cultural elements, such as values, beliefs and normative expectations (Haveman & Gualtieri, 2017).

Most scientists identified that if a proposal was *innovative*, and could be implemented in the health sector, it was more likely to be funded. Innovation here is in accord with the OECD definition, discussed earlier. Scientists could adapt to this by pragmatically acknowledging their role as making a discovery that could end up being commercialised, and supporting the logics of *economic growth* and *investment*, in addition to helping people. EDC researchers fell outside this narrative as their work did not reflect the OECD innovation definition. They considered that their work was to explore the potential for economic activities to cause harm through pollution from household and industrial chemicals. Their work was difficult to regard as an *investment*, as it often inferred drew attention to harm from household and industrial activities. By comparison, investment logics complemented biomedical research.

Translation was a term I had been previously unfamiliar with. The aetiology of translation is directly biomedical, referring to the delivery of diagnostics and drug development into the health sector. Many scientists recognised that their work had to be translatable into the health sector. After researching the historical context of the key term translation, I could identify how the controlling process operated. If proposals were not innovative nor translatable, they were unlikely to be funded. Together, innovation and translation steered FP's towards biomedical research inside the health sector. This research typically pursued research for diagnostics or treatment for a *single disease.*

The medicalisation of scientist peers on FP's was an important controlling factor that I had not taken into account prior to the interview process. From this perspective, scientists and clinicians with positions on FP's were likely to regard policy content emphasising innovation, translation and equity inside the health sector as normative. This perhaps suggests that FP's consider that social scientists and epidemiologists have a public health role in drawing attention to the SEDH, and expect physical scientists to normatively pursue biomedical research. While this is speculation, this may explain why policy that is so prescriptively biomedical remains unquestioned. Therefore, while FP's were normally concerned with how scientific research into genetic and biological functioning could be translated into the health sector, EDC researchers were directly concerned with the exposome, in elucidating non-genetic influences on biological functioning that were not innovative, and not so easily translated inside the health sector.

KEY POLICY TERMS: **INNOVATION, TRANSLATION, EQUITY**



In addition, the key term *equity* appeared to constrain for physical science research. This focus on equity inside the health sector ignores the role physical scientists can play in drawing attention to non-voluntary environmental exposures that can disproportionately impact lower socioeconomic and marginalised populations. Equity of treatment in the health sector fails to draw attention to the role primordial *prevention* policies can play in avoiding disease, particularly in infancy and childhood. In addition, common diseases often are associated with other morbidities, further problematising the *single disease* approach to research.

Scientists identified that peers and funding panels struggled to prioritise EDC research, and could express considerable *skepticism* as to the fields' relevance. This contrasted somewhat paradoxically with the normative acceptance that drugs commonly target hormonal pathways.

I could observe most participants struggled to secure funding if they engaged in research that was outside normative innovative, translation and equity framing and which diverted from biomedical logics. Hypercompetitive funding environments increased the potential for safe projects to be approved and non-conforming proposals to be downgraded.

Chapter 8. Conclusion

> *Professor (B): We have to understand the weight of the issue. We have to understand the extent to which this contributes to the problem we're struggling with in our chronic disease health burden. We have to understand the mechanisms by which that effect is manifesting, and we have to begin to provide solutions.*

This thesis commenced with a query: "why and how does New Zealand remain silent on the matter of endocrine disrupting compounds (EDCs)?" Other OECD nations have well-established policy, scientific institutes and researchers with expertise in this field. Emissions from manmade chemicals are increasingly factored alongside CO2 as a threat to human resilience, and a science enterprise centred around the production of innovative technologies may instead be perilous, as it displaces policy relevant knowledge that might ensure a safe space for future generations (Raworth, 2017 ; Steffen, et al., 2015). My query arose from this perspective: if society cannot understand the risk posed by modern technologies, society cannot appropriately steward them.

My research question echoes a global dilemma. While the expansion of genetic and molecular knowledge over the 20th and early 21st century has been incredibly valuable and important, biomedical knowledge expansion has failed to make a space for equally valid research that explore the primary drivers of health and disease. In particular, research exploring environmental, rather than genetic factors, remains under-valued and undone (Barouki et al.2018). This is important because exposures from endocrine disrupting compounds can set in place cascading effects, involving biological, social and cultural feedback loops.

My research revealed that funding environments marginalise the role of environmental pollutants through the use of key terms in policy, and associated economic, political and cultural logics. I identified that key terms in the policy documents emphasise economic growth and productivity, require research to be innovative, translational and promote equity. These terms work as controlling processes, directing research to produce potentially marketable outputs, such as diagnostic and treatment technologies, for application inside the health sector.

The interviews revealed structural factors (key terms) and normative cultures (logics) that produced pervasive barriers to any research that didn't conform to those terms and logics, making such research vulnerable to being downgraded and deprioritised (denied). The interviews highlighted the pressure for scientists to undertake biomedical research. Biomedical logics on funding panels harmonise with policy literature emphasising innovation and translation. I interviews suggest that

physical scientists working in health research are normatively expected to pursue biomedical research. Funding for biomedical innovation elides exploratory and diagnostic science, as Dryzek (2008, p. 3) has noted "[d]iscourses, in contrast, can be so ingrained that subjects are unaware of their presence (…) What an outsider can see as a discourse, an insider will often take for granted as the natural order of things" (p. 3).

Pervasive non-knowledge and the absence of a critical mass of authoritative experts appeared to contribute to not only explain how funding was difficult, but how the situation was perpetuated; why guiding policies contained no mechanism to facilitate non-biomedical physical science; and why scientists in this field struggled to equip research laboratories.

State Goals: Science for Economic Growth

I identified economic growth norms in the New Zealand policy and health research literature that shaped state preferences towards funding that would be likely to contribute to economic growth. A constant theme throughout the literature was the requirement and support for biomedical research that could be commercialised, and the insights of scientists reflected this perspective.

Investment and accountability metrics emphasising economic growth and instrumental approaches to innovation, function in policy as apolitical mechanisms. While implying responsibility in the delegation of public funds. however, I contend these mechanisms instead marginalising science that drew attention to the exigencies of economic activity, that economic growth represented a value that protected polluting interests.

Ignorance

> "A paradigm can, for that matter, even insulate the community from those socially important problems that are not reducible to puzzle form, because they cannot be stated in terms of the conceptual and instrumental tools the paradigm applies" (Kuhn, 1970, p. 37).

I propose that contemporary institutional arrangements effectively depoliticise and marginalise EDC research, which can produce 'uncomfortable knowledge' and draw attention to the social drivers of disease. Uncomfortable knowledge is knowledge that, if produced is likely to conflict with organisational principles and goals. While uncomfortable knowledge can be strategically suppressed, institutional arrangements can simply leave science unfunded and undone (Rayner, 2012). For scientists, the current arrangements ensured their research was deprioritised by funding bodies, and remained unfunded. The controlling processes, as key terms and dominant logics, acted to frame out uncertainty and ignorance by pushing EDC proposals down the list for prospective

funding. However, the consequence of the policy terms (or rules), aligned logics and the institutional ignorance created (as an expertise void), produced sustained feedback loops (see Table 1), eroding the potential for this work to commence. Hypercompetitive funding environments exacerbated the risk for FPs and scientists.

These arrangements actively produced ignorance regarding the importance of EDC research for human health.

Table 1

The Changing Political Sphere

The current funding climate is a consequence of three decades of policy that has emphasised neoliberal investment and innovation narratives. The shift to a Labour government has seen a subsequent softening of policy, as identified in the Prioritisation Framework (HRC, MBIE, MoH, 2019) and Impact Assessment (HRC, 2019). However, contradictions remain as productivity metrics appear dominant measures for the Ministry responsible for the science budget (MBIE, 2018; MBIE, 2020a). Without a space being created for non-orthodox, non-innovative physical science research exploring the SEDH, it is likely that this often ambiguous research will be outcompeted by more certain, accountable and familiar research.

However, I suggest that without structural changes supporting health research in the physical sciences to specifically address environmental exposures and stressors, the politically delicate nature of exposome and EDC research will ensure that it continues to be displaced by other less politically controversial lines of research.

Limits and Future Research

The absence of EDC research being undertaken is but one example of a larger phenomenon, and future research should examine the funding situation for other potentially controversial fields of research. Additionally, while I illuminated the New Zealand case, we need to examine the situation in other countries where EDC research is an established multidisciplinary field.

The international literature identifies that biomedical research has access to far more resourcing than environmental health research. Research exploring the level of investment in health research directed towards biomedical development, versus the level of directed towards physical sciences exploring the exposome, as the social and environmental determinants of disease and health (SEDH), could shed light on balance of funding in New Zealand. In addition, exploration of the increasing cost of health provision and the interconnected expense of welfare and disability as a proportion of the national budget could shed light on the relatively minor funding of health research targeted to explore the SEDH.

Research exploring the EDC environment in Denmark and other small OECD nations could draw attention to the political, regulatory, social and cultural processes that have resulted in Denmark progressing in this field. Exploration of the relative autonomy and flexibility of environmental health research institutes could be undertaken, and in particular, the potential for access to longer-term funding. Other governance factors may be associated with field advancement: Different

regulatory arrangements; the presence of public-good legislation; the degree to which regulatory oversight is updated and reflective of literature outside industry data; and the degree to which decision-making processes are enhanced through use of the precautionary principle, may all play a role.

Important research could explore the degree to which scientists seeking to draw attention to pollution across the New Zealand landscape, in human bodies, soil, freshwater and groundwater have access to secure long-term funding or have experienced difficulty securing resources and are inhibited by short-term contractual arrangements. Maintaining high-level laboratories involves long-term resource commitment, particularly if scientific methods and instrumentation are to keep pace with best international practice.

New Zealand-based research could explore whether the phenomenon of directing research towards applied innovative science displaces exploratory basic research can be observed in policy and decision-making logics in other sectors. For example, has a long-term genetic predisposition restricted the capacity to fund basic science in other fields? Do scientists have easier access to funding for genomic research in plant biology, than to research soil health for disease resistance? In a similar vein, do funding processes for soil science struggle with basic, exploratory and non-normative approaches to understanding complex soil systems? Is research funding pollution from synthetic chemicals in soil, drinking-water and freshwater difficult to secure, particularly if it is exploratory and cannot realise an innovative output?

Final Comments

The provision of adequate diagnostics, treatments and services inside the health sector in the face of accumulating multimorbid conditions in children represents a failure of the Government obligation to protect health. The structural capture of health research for engagement inside the health sector has been roundly criticised as it depoliticises and distracts policy and research from the political, economic, social and environmental determinants that more powerfully define health and wellbeing (Baker, et al., 2018; Marmot, 2018). I acknowledge that recent changes in policy may ameliorate this legacy position (HRC, MBIE, MoH, 2019). However, I suggest that without structural changes supporting health research in the physical sciences to specifically address environmental exposures and stressors, the politically delicate nature of exposome and EDC research will ensure that it continues to be displaced by other less politically controversial lines of research.

In conclusion, I defer to a values proposition as per Navarro (2011) who maintains “[p]ublic health is not a branch of medicine. Rather, medicine is a branch of public health” (p. 118).

Navarro reminds us of the fact that health is public, and public investment in health research should be guided by a social contract that ensures investment is dedicated to advancing knowledge, preventing disease and protecting health at the population level.

Appendices

Appendix A: Participant Information Sheet

Sociology
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PARTICIPANT INFORMATION SHEET

Project title: Mind the research gap: Do institutional structures and norms encourage or deter research into the human health impact of hormone disrupting synthetic chemicals?

Name of Principal Investigator/Supervisor (PI): Manuel Vallée

Name of Student Researcher(s): Jodie Bruning

Researcher introduction

The researcher is undertaking the research project as a requirement of a Master of Arts Sociology (Research) program at the University of Auckland.

Project description and invitation

The project aims to provide insight into the institutional and structural influences that shape the production of scientific knowledge. To shed light on this phenomenon, I am interviewing researchers in public health and endocrinology fields in Australia and New Zealand, with the aim of better understanding the structural forces that shape which research projects gets pursued.

I am asking you to participate in this project because, as someone who has been involved in endocrinology and human health research, you will have an informed perspective on the social dynamics that determine which projects get pursued. Your work may not directly involve research

relating to exogenous chemicals that can alter hormones and create the conditions for disease, disability and disorder. There are few scientists who have direct expertise in this field in New Zealand. However you may have some insights in relation to the social, institutional, cultural and historical forces that shape the orientation of research.

Project Procedures

Under 20 participants with expertise in endocrinology and/or toxicology research will be invited to join this qualitative research project. Participants will be invited to participate in semi-structured open-ended 1-on-1 interviews, predominantly via Skype or Zoom. Interviews are anticipated to take roughly 45-60 minutes.

You will be asked to sign a standard consent form which will give consent for the interview and for recording for transcription purposes. Once transcription is completed the word document can be forwarded to you for review and request corrections if necessary (two weeks are provided for your review process).There is no funding for this research.

Data storage/retention/destruction/future use

If audio recordings are permitted by you, that data will be transcribed by the researcher. You can request that the recording is turned off at any time. No third parties will be involved in translating, interpreting, recording, entering or destroying data. Recordings will not be transferred to a public repository. The recording and research data will be stored on a University of Auckland managed computer file hard drive for 6 years and then destroyed Recording is optional but preferred for accuracy. The recorder can be turned off at any time. Recordings and transcripts will not be shared with third parties (including employers or heads of department).

Right to Withdraw from Participation

Participation in this research project is voluntary. The interview can be terminated at any point or the recording device turned off at any point without giving reason. You have the right to withdraw from participation at any time without giving a reason.

Anonymity and Confidentiality

Your identity will be kept confidential and no identifying information will be published. The data will be de-identified through coding after the audio file is transcribed.

The research has been expanded to include Australian scientists so as to ensure anonymity and confidentiality of the New Zealand scientists. Due to the limited field that is this specialist areas of expertise, there may be capacity for you to be identified. Neither your organisation details, nor country of residence will be published.

Minimising harm: potential risks will be discussed with all participants regarding confidentiality as it will be a small Australian/New Zealand cohort.

You can review transcripts and request that claims, quotes and/or opinions that may breach confidentiality and publicly identify you and that you consider represent social, cultural or professional risk to yourself, will not be included in the final research paper This can be withdrawn up to one month after your interview.

A summary of findings will be made available at the conclusion of the project.

Contact Details

Should you have any concerns regarding this research project we invite you to contact either:

Researcher: Jodie Bruning Email: jbru498@aucklanduni.ac.nz

Principal Investigator: Manuel Vallée Email: m.vallee@auckland.ac.nz

Head of School: Professor Simon Holdaway Email: sj.holdaway@auckland.ac.nz

For any queries regarding ethical concerns you may contact the Chair, The University of Auckland Human Participants Ethics Committee, Office of Research Strategy and Integrity, The University of Auckland, Private Bag 92019, Auckland 1142. Telephone 09 373-7599 ext. 83711. Email: humanethics@auckland.ac.nz

Approved by the University of Auckland Human Participants Ethics Committee on June 17 2020 for three years. Reference Number 024553

Appendix B: Participant Consent Form

THE UNIVERSITY OF AUCKLAND
NEW ZEALAND
Te Whare Wānanga o Tāmaki Makaurau

Sociology
The University of Auckland
Private Bag 92019
Auckland, New Zealand
Telephone 64 9 373 7599 ext. 88614
Email: sociology@auckland.ac.nz
Website: www.arts.auckland.ac.nz/soc

PARTICIPANT CONSENT FORM

THIS FORM WILL BE HELD

FOR A PERIOD OF 6 YEARS

Project title: Mind the research gap: Do institutional structures and norms foster or deter research into the human health impact of hormone disrupting chemicals?

Name of Principal Investigator/Supervisor (PI): Manuel Vallée

Name of Student Researcher(s): Jodie Bruning

- I have read the Participant Information Sheet, have understood the nature of the research and why I have been selected. I have had the opportunity to ask questions and have had them answered to my satisfaction. I understand that as a participant my identity will be kept confidential and no identifying information will be published.

- I agree to take part in this research.

- I understand that I am free to withdraw my participation at any time, and to withdraw any data traceable to me up to one month after the interview.

- I agree / do not agree to be audio recorded (this is optional but a digital record of the interview is preferred to ensure accurate transcription and interpretation of data).

- If I agree to be audio recorded, I understand that I may choose to have the recorder turned off at any time.

- I understand that recordings will be transcribed by the researcher (Jodie Bruning).

  I wish to receive a transcript of my interview for review and editing, and understand I will have two weeks from the time I receive it to edit it. Please circle: Yes or No

- I wish/do not wish to receive a summary of findings, which can be emailed to me at

  this email address: _____

Name: _____

Signature: _____ Date: _____

Approved by the University of Auckland Human Participants Ethics Committee on June 2020

for three years. UAHPEC Reference Number 024553

Bibliography

Acheson, D. (1988). *Public health in England. The report of the committee of inquiry into the future development of the public health function.* HMSO.

Adler, N., & Newman, K. (2002). Socioeconomic disparities in health: Pathways and Policies. *Health Affairs, 21*, 60-76.

Ajwani, S., Blakely, T., Robson, B., Tobias, M., & Bonne, M. (2003). *Decades of Disparity. Ethnic Mortality Trends in New Zealand 1980-1999.* Wellington: Ministry of Health and University of Otago.

Alberts, B., Kirschner, M., Tilghman, S., & Varmus, H. (2014). Rescuing US biomedical research from its. *PNAS, 111*(16), 5773-5777.

Althaus, C. (2005). A disciplinary perspective on the epistemological status of risk. *Risk Analysis, 25*(3), 567-588.

Anderson, M., Ronnin, E., De Vries, R., & Martinson, B. (2007). The Perverse Effects of Competition on Scientists' Work and Relationships. *Sci Eng Ethics, 13*, 437-461.

Archibugi, D., & Filipetti, A. (2018). The retreat of public research and its adverse consequences on innovation. *Technological Forecasting & Social Change*, 97-111.

Armstrong, D. (1993). History of Opportunistic Infection in the Immunocompromised Host. *Clinical Infectious Diseases, 17*(2), S318-S321.

Arundel, A. (2016). Metrics for the commercialisation of knowledge produced by public research organisations. *The World Intellectual Property Organization (WIPO): International Comparison of Knowledge Transfer Policies and Practices*, (pp. 1-17). Beijing: University of Tasmania.

Assefa, S., & Köhler, G. (2020). Intestinal microbiome and metal toxicity. *Current Opinion in Toxicology, 19*, 21-27.

Attina, T., Hauser, R., Sathyanarayana, S., Hunt, P., Bourguignon, J., Myers, J., . . . Trasande, L. (2016). Exposure to endocrine-disrupting chemicals in the USA: a population-based disease burden and cost analysis. Lancet Diabetes Endocrinol 2016; 4: 996–1003. *Lancet Diabetes*

and Endocrinology, 4(12), 996-1003. Retrieved from https://www.thelancet.com/journals/landia/article/PIIS2213-8587(16)30275-3/fulltext

Auranen, O., & Nieminen, M. (2010). University research funding and publication performance—An international comparison. *Research Policy, 39*, 822-834.

Azoulay, P., Graff Zivin, J., & Manso, G. (2011). Incentives and creativity: evidence from the academic life sciences. *RAND Journal of Economics*, 527-554.

Bacchi, C. (2016). Problematizations in Health Policy: Questioning How "Problems" Are Constituted in Policies. *SAGE Open*, 1-16.

Bacchi, C., & Goodwin, S. (2016). *Poststructural Policy Analysis A Guide to Practice.* New York: Springer Nature.

Baker, P., Friel, S., Kay, A., Baum, F., Strazdins, L., & Mackean, T. (2018). What Enables and Constrains the Inclusion of the Social Determinants of Health Inequities in Government Policy Agendas? A Narrative Review. *Int J Health Policy Manag, 7*(2), 101-111.

Baker, P., Machado, P., Santos, T., Sievert, K., Backholer, K., Hadjikakou, M., . . . Lawrence, M. (2020). Ultra-processed foods and the nutrition transition: Global, regional and national trends, food systems transformations and political economy drivers. *Obesity Reviews*.

Ball, S. (2015). What is policy? 21 years later: reflections on the possibilities of policy research. *Discourse: Studies in the Cultural Politics of Education*, 306-313.

Ball, S. J. (1993). What is policy? Texts, trajectories and toolboxes. *Discourse: Studies in the Cultural Politics of Education, 13*(2), 10-17.

Bambra, C., Fox, D., & Scott-Samuel, A. (2005). Towards a politics of health. *Health Promotion International,, 20*(2), 187-193.

Bambra, C., Riordan, R., Ford, J., & Matthews, F. (2020). The COVID-19 pandemic and health inequalities. *J Epidemiol Community Health, 74*, 964-968.

Barouki, R. (2017). Endocrine disruptors: Revisiting concepts and dogma in toxicology. *Comptes Rendus Biologies, 340*, 410-413.

Barouki, R., Audouze, K., Coumoul, X., Demenais, F., & Gauguier, D. (2018). Integration of the human exposome with the human genome to advance medicine. *Biochimie*, 155-158.

Barouki, R., Gluckman, P. D., Grandjean, P., Hanson, M., & Heindel, J. J. (2012). Developmental origins of non-communicable disease: Implications for research and public health. *Environmental Health*, 42.

Bateson, G. (1972). *Steps to an Ecology of Mind.* New York: Ballantine Books.

Baum, F. (2019). *Governing for Health: Advancing Health and Equity through Policy and Advocacy.* Oxford University Press.

Beaglehole, R., & Bonita, R. (1997). *Public Health at the Crossroads: Achievements and prospects* (2nd ed.). Cambridge University Press.

Becker, H. (1963). *Outsiders: Studies in the sociology of deviance.* The Free Press of Glencoe.

Bennet, D., Bellinger, D., Birmbaum, L., Bradman, A., Chen, A., Cory-Slechta, A., . . . Marquez, E. (2016). roject TENDR: Targeting Environmental Neuro-Developmental Risks The TENDR Consensus Statement. *Environmental Health Perspectives*, A118-A122.

Bentley, P., Gulbrandsen, M., & Kyvik, S. (2015). The relationship between basic and applied research in universities. *Higher Education*, 689-709.

Bhattacharya, J., & Packalen, M. (2011). Opportunities and benefits as determinants of the direction of scientific research. *Journal of Health Economics*, 603-615.

Blakely, T., Kvizhinadze, G., Atkinson, J., & Dieleman, J. (2019). Health system costs for individual and comorbid noncommunicable diseases: An analysis of publicly funded health events from New Zealand. *PLOS Medicine*, e1002716.

Blume, S. (1974). *Toward a Political Sociology of Science.* New York: Free Press.

Boudia, S., Craeger, A., Frickel, S., Henry, E., Jas, N., Reinhardt, C., & Roberts, J. (2018). Residues: Rethinking Chemical Environments. *Engaging Science, Technology, and Society, 4*, 165-178.

Bourdieu, P. (1986). The forms of capital. In J. Richardson, *Handbook of theory and research for sociology of education* (pp. 241-258). New York: Greenwood Press.

Bourdreau, K., Guinan, E., Lakhani, K., & Riedl, C. (2012). *The Novelty Paradox & Bias for Normal Science: Evidence from Randomized Medical Grant Proposal Evaluations. Working Paper, No. 13–053.* Harvard Business School.

Bourdreau, K., Guinan, E., Lakhani, K., & Riedl, C. (2016). Beyond the Knowledge Frontier: Intellectual Distance, Novelty, and Resource Allocation in Science. *Management Science, 62*(10), 2765-2783.

Bozeman, B., & Youtie, J. (2017). Socio-economic impacts and public value of government-funded research: Lessons from four US National Science Foundation initiatives. *Research Policy*, 1387-1398.

Bradford Hill, A. (1965/2015). The environment and disease: association or causation? *The Royal Society of Medicine, 108*(1), 32-37.

Brandt, A., & Gardner, M. (2000). Antagonism and accommodation: interpreting the relationship between public health and medicine in the United States during the 20th century. *American Journal of Public Health*, 707-715.

Brannen, J. (2005). *Mixed Methods Research: A discussion paper.* London: ESRC National Centre for Research Methods NCRM Methods Review Papers. NCRM/005.

Braun, D. (1998). The role of funding agencies in the cognitive development of science. *Research Policy*, 807-821.

Brehm, E., & Flaws, J. (2019). Transgenerational Effects of Endocrine-Disrupting Chemicals on Male and Female Reproduction. *Endocrinology, 160*(6), 1421-1435.

Brenner, N., Peck, J., & Theodore, N. (2010). Variegated neoliberalization: geographies, modalities, pathways. *Global Networks*, 182-222.

Briggs, A., Wolstenholme, J., Blakely, T., & Scarborough, P. (2016). Choosing an epidemiological model structure for the economic evaluation of non-communicable disease public health interventions. *Population Health Metrics, 14*. doi:10.1186/s12963-016-0085-1

Brinkmann, S., & Kvale, S. (2019). *Doing Interviews.* SAGE Publications.

Brown, P. (1995). Naming and framing: the social construction of diagnosis and illness. *Journal of Health and Social Behavior*, 34-52.

Brown, P. (1997). Popular Epidemiology Revisited. *Current Sociology*, 137-156.

Brown, P., McCormick, S., Mayer, B., Zavestoski, S., Morello-Frosch, R., Altman, R., & Senier, L. (2006). “A Lab of Our Own” Environmental Causation of Breast Cancer and Challenges to

the Dominant Epidemiological Paradigm. *Science, Technology and Human Values, 31*(5), 499-536.

Buckle, R., & Creedy, J. (2017). *The Evolution of Research Quality in New Zealand Universities as Measured by the Performance-Based Research Fund Process. Working paper 11/2017.* Victoria University .

Burkett, J., & Miller, G. (2021). Using the exposome to understand environmental contributors to psychiatric disorders. *Neuropsychopharmacology, 46*, 263-264.

Came, H. (2014). Sites of institutional racism in public health policy making in New Zealand. *Social Science & Medicine, 106*, 214-20.

Carran, M., & Shaw, I. (2012). New Zealand Malayan war veterans' exposure to dibutylphthalate is associated with an increased incidence of cryptorchidism, hypospadias and breast cancer in their children. *NZMJ*, 52-63.

Carson, R. (1962). *Silent Spring.* Houghton Mifflin.

Casadevall, A. (2018). Is the Pace of Biomedical Innovation Slowing. *Perspectives in Biology and Medicine*, 584-593.

Casadevall, A., & Pirofski, L. (2018). What Is a Host? Attributes of Individual Susceptibility. *Infection and Immunity*, 86:e00636-17.

Casper, M. (2003). *Synthetic planet: chemical politics and the hazards of modern life.* Routledge.

CeHoS. (2021, 01 08). *Centre for Endocrine Disruptors*. Center for Hormonforstyrrende Stoffers: http://cend.dk/

Chavarro, D., Tang, P., & Ràfols, I. (2016). *Why researchers publish in non-mainstream journals: Training, knowledge bridging, and gap filling.* University of Sussex.

Christensen, V., & Casper, M. (2000). Hormone Mimics and Disrupted Bodies: Social worlds analysis of a scientific controversy. *Sociological Perspectives* S93-S120.

Chubin, D., & Hackett, E. (1990). *Peerless Science. Peer Review and U.S. Science Policy.* State University of New York Press.

Clarke, A., & Shim, J. (2011). Medicalization and Biomedicalization Revisited. In *Handbook of the Sociology of Health, Illness, and Healing: A Blueprint for the 21st Century* (pp. 173-200). Springer.

Clarke, G., Sandhu, K., Griffin, B., Dinan, T., Cryan, J., & Hyland, N. (2019). Gut Reactions: Breaking Down Xenobiotic–Microbiome Interactions. *Pharmacological Reviews, 71*(2), 198-224.

Claus, S., Guillou, H., & Ellero-Simatos, S. (2016). The gut microbiota: a major player in the toxicity of environmental pollutants? *NPJ Biofilms and Microbiomes, 2*.

Cohen, M. (2000). Changing patterns of infectious disease. *Nature*, 762-767.

Cohrs, R., Martin, T., Ghahramani, P., Bidaut, L., Higgins, P., & Shahzad, Z. (2015). Translational Medicine definition by the European Society for Translational Medicine. *New Horizons in Translational Medicine, 2*, 86-88.

Colborn, T., Myers, J., & Dumanoski, D. (1997). *Our Stolen Future: Are We Threatening Our Fertility, Intelligence, and Survival? A Scientific Detective Story.* Plume.

Collins, H. M. (1974). The TEA Set: Tacit Knowledge and Scientific Networks. *Science Studies*, 165-185.

Conrad, P. (2005). The Shifting Engines of Medicalization. *Journal of Health and Social Behaviour, 46*, 3-14.

Cordner, A. (2015). Strategic Science Translation and Environmental Controversies. *Science, Technology, & Human Values*, 915-938.

Croissant, J. (2014). Agnotology: Ignorance and Absence or Towards a Sociology of Things that Aren't There. *Social Epistemology*, 4-25.

Crutzen, P. (2002). Geology of mankind. *Nature, 415*(3), 23.

D'Alisa, G., & Kallis, G. (2016). A political ecology of maladaptation: Insights from a Gramscian theory of the State. *Global Environmental Change, 38*, 230-242.

Daroudi, R., Sari, A., Nahvijou, A., & Faramarzi, A. (2021). Cost per DALY averted in low, middle-and high-income countries: evidence from the global burden of disease study

to estimate the cost-effectiveness thresholds. *Cost Effectiveness and Resource Allocation, 19*(7).

Day, T. (2015). The big consequences of small biases: A simulation of peer review. *Research Policy, 44*(6), 1266-1270.

Delgado, A., & Am, H. (2018). Experiments in interdisciplinarity: Responsible research and innovation and the public good. *PLOS Biology*, e2003921.

Demeneix, B. (2017). *Toxic Cocktail. How chemical pollution is poisoning our brains.* Oxford University Press.

Demeneix, B. (2019). Evidence for Prenatal Exposure to Thyroid Disruptors and Adverse Effects on Brain Development. *European Thyroid Journal, 8*, 283-292.

Demeneix, B., & Slama, R. (2019). *Endocrine Disruptors: from Scientific Evidence to Human Health Protection. requested by the European Parliament's Committee on Petitions. PE 608.866 - March 2019.* Brussels: Policy Department for Citizens' Rights and Constitutional Affairs.

Demeritt, D. (2000). The New Social Contract for Science: Accountability, Relevance and Value in US and UK Science and Research Policy. *Antipode, 32*(3), 308-329.

Dew, K. (2012). *The Cult and Science of Public Health.* Berghahn Books.

Dew, K. (2019). *Public Health, Personal Health and Pills.* Routledge.

Dryzek, J. (2008). Paradigms and Discourses. In D. Bodansky, J. Brunnée, & E. Hey (Eds.), *The Oxford Handbook of International Environmental Law.* Oxford University Press.

Dryzek, J. S. (2013). *The Politics of the Earth: Environmental Discourses.* Oxford University Press.

E.C. (2021, 01 21). *Endocrine Disruptors.* European Commission https://ec.europa.eu/environment/chemicals/endocrine/index_en.htm#:~:text=The%20EU%20has%20introduced%20specific,substances%20of%20very%20high%20concern.

Edwards, R. (2020). Why do academics do unfunded research? Resistance, compliance and identity in the UK neo-liberal university. *Studies in Higher Education*. https://doi.org/10.1080/03075079.2020.1817891

Encarnação, T., Pais, A., Campos, M., & Burrows, H. (2019). Endocrine disrupting chemicals: Impact on human health, wildlife and the environment. *Science Progress*, 3-42.

Entman, R. (1993). Framing: Toward clarification of a fractured paradigm. *Journal of Communication, 43*, 51-74.

ESR. (2020a). *Health risk assessment reports*. https://www.esr.cri.nz/home/about-esr/our-science-in-action/health-risk-assessment-reports/

ESR. (2020b). *Statement of Corporate Intent 2020-2025.* The Institute of Environmental Science and Research Limited (ESR). https://www.esr.cri.nz/assets/ABOUT-ESR-CONTENT/ESR-Statement-of-Intent-2020-2025.pdf

Etzkowitz, H., & Leydesdorff, L. (2000). The dynamics of innovation: from National Systems and ‘‘Mode 2’’ to a Triple Helix of university–industry–government relations. *Research Policy*, 109-123.

Exworthy, M. (2008). Policy to tackle the social determinants of health: using conceptual models to understand the policy process. *Health Policy and Planning, 23*, 318-327.

Ezrahi, Y. (2003). Science and the Postmodern Shift in Contemporary Democracies. In B. Joerges, & H. Nowotny, *Social Studies of Science and Technology: Looking Back Ahead* (pp. 63-75). Kluwer Academic Publishers.

Fang, F., & Casadevall, A. (2015). Competitive Science: Is Competition Ruining Science? *Infection and Immunity*, 1229-1233.

Ferrari, S., Fallahi, P., Elia, G., Ragusa, F., Ruffilli, I., Patrizio, A., . . . Antonelli, A. (2019). Autoimmune Endocrine Dysfunctions Associated with Cancer Immunotherapies. *International Journal of Molecular Sciences*, 2560.

Ferretti, F., Pereira, A., Vertesy, D., & Hardeman, S. (2018). Research excellence indicators: time to reimagine the ‘making of’? *Science and Public Policy, 45*(5), 731-741.

Fleck, L. (1935/1979). *The Genesis and Development of a Scientific Fact.* University of Chicago Press.

Flier, J., & Loscalzo, J. (2017). Categorizing biomedical research: the basics of translation. *FASEB Journal*, 3210-3215.

Fochler, M., Felt, U., & Muller, R. (2016). Unsustainable Growth, Hyper-Competition, and Worth in Life Science Research: Narrowing Evaluative Repertoires in Doctoral and Postdoctoral Scientists' Work and Lives. *Minerva, 54*, 175-200.

Fontana, M., Iori, M., Montobbio, F., & Sinatra, R. (2020). New and atypical combinations: An assessment of novelty and interdisciplinarity. *Research Policy*, 104063.

Fortin, J., & Currie, D. (2013). Big Science vs. Little Science: How Scientific Impact Scales with Funding. *PLOS One*, e65263.

Foucault, M. (1979). Governmentality. *Ideol. Conscious, 6*, 5-21.

Foucault, M. (1982). The Subject and Power. *Critical Inquiry, 8*, 777-795.

Franssen, T., Scholten, W., Hessels, L., & de Rijke, S. (2018). The Drawbacks of Project Funding for Epistemic Innovation: Comparing Institutional Affordances and Constraints of Different Types of Research Funding. *Minerva, 56*, 11-33.

Freeman, C. (1995). The 'National System of Innovation' in historical Perspective. *Cambridge Journal of Economics*, 5-24.

Frickel, S. (2014). Not Here and Everywhere: The NonProduction of Scientific Knowledge. In D. Kleinman, & K. Moore, *Routledge Handbook of Science, Technology and Society* (pp. 263-276). Routledge.

Frickel, S., & Moore, K. (Eds.). (2006). *The New Political Sociology of Science.* The University of Wisconsin Press.

Friedrichs, J. (2011). Peak energy and climate change: The double bind of post-normal science. *Futures*, 469-477.

Friel, S., Loring, B., Aungkasuvapala, N., Baum, F., Blaiklock, A., Chiang, T., . . . Surjadi, C. (2012). Policy Approaches to Address the Social and Environmental Determinants of Health Inequity in Asia-Pacific. *Asia Pacific Journal of Public Health, 6*, 896-914.

Fuller, R., Rahona, E., Fisher, S., Caravanos, J., Webb, D., Kass, D., . . . Landrigan, P. (2018). Pollution and non-communicable disease: time to end the neglect. *The Lancet, 2*, e96-e98.

Funtowicz, S., & Ravetz, J. (1995). Science for the Post Normal Age. In L. Westra, & J. Lemons, *Perspectives on Ecological Integrity. Vol.5* (pp. 146-161). Springer-Science+Business Media, B.V. .

Gabb, H., & Blake, C. (2016). An Informatics Approach to Evaluating Combined Chemical Exposures from Consumer Products: A Case Study of Asthma-Associated Chemicals and Potential Endocrine Disruptors. *Environ Health Perspect, 124*, 1155-1165.

Gaudillière, J. (2014). DES, Cancer, and Endocrine Disruptors Ways of Regulating, Chemical Risks, and Public Expertise in the United States. In S. Boudia, & N. Jas, *Powerless Science? : Science and Politics in a Toxic World* (pp. 65-94). Oxford: Berghahn Books.

Gauld, R., Bloomfield, A., Kiro, C., Lavis, J., & Ross, J. (2006). Conceptions and uses of public health ideas by New Zealand government policymakers: report on a five-agency survey. *Public Health, 120*, 283-289.

GBD 2019 Viewpoint Collaborators. (2020). Five insights from the Global Burden of Disease Study 2019. *The Lancet*, 1135-1159.

Gibbons, M., Limoges, C., Nowotny, H., Schwartzman, S., Scott, P., & Trow, M. (1994). *The New Production of Knowledge. The Dynamics of Science and Research in Contemporary Societies.* Thousand Oaks: SAGE Publications.

Gieryn, T. (1995). Boundaries of Science. In S. Jasanoff, G. Markle, J. Peterson, & T. Pinch, *The Handbook of Science and Technology Studies* (pp. 393-443). Sage Publications.

Gläser, J., & Laudel, G. (2016). Governing Science how science policy shapes research content. *European Journal of Sociology, 57*(1), 117-168.

Gläser, J., Lange, S., Laudel, G., & Schimank, U. (2010). The Limits of Universality. In R. Whitley, J. Gläser, & L. Engwall (Eds.), *Reconfiguring Knowledge Production: Changing Authority Relationships in the Sciences and their Consequences for Intellectual Innovation.* Oxford Scholarship Online. doi:10.1093/acprof:oso/9780199590193.003.0010

Gluckman, P. (2018). The role of evidence and expertise in policy-making: the politics and practice of science advice. *Journal & Proceedings of the Royal Society of New South Wales, 151*(1), 91-101.

Gluckman, P. (2021, April 13). *Public lecture – COVID-19 recovery: Towards a just and sustainable society.* Koi Tū: The Centre for Informed Futures: https://informedfutures.org/iiasa-lecture/

Gotkin, J. (2012). *United States Bayh-Dole Act and its Effect on University Technology Transfer.* Nomos Verlagsgesellschaft mbH.

Grandjean, P., & Bellanger, M. (2017). Calculation of the disease burden associated with environmental chemical exposures: application of toxicological information in health economic estimation. *Environmental Health123, 16*.

Gravida. (2020, August 30). *About Us*. http://www.gravida.org.nz/about-us/

Greener, I. (2002). Theorising path-dependency: how does history come to matter in organisations? *Management Decision*, 614-9.

Gregory, G. (2016). A better way: New Zealand Association of Scientists 1992–2016. *New Zealand Science Review, 73*, 42-54.

Grove, L. (2017). *The effects of funding policies on academic research. Doctoral thesis.* University College London.

Gruening, G. (2001). Origin and theoretical basis of New Public Management. *International Public Management Journal, 4*, 1-25.

Guimarães, M., Pohl, C., Bina, O., & Varanda, M. (2019). Who is doing inter- and transdisciplinary research, and why? An empirical study of motivations, attitudes, skills, and behaviours. *Futures, 112*.

Gupta, R., Kumar, P., Fahmi, N., Garg, B., Dutta, S., Sachar, S., . . . Vimaleswaran, K. (2020). Endocrine disruption and obesity: A current review on. *Current Research in Green and Sustainable Chemistry, 3*, 100009.

Guston, D., Woodhouse, E., & Sarewitz, D. (2001). A Science and Technology Policy Focus for the Bush Administration. *Issues in Science and Technology, 17*(3).

Hackett, E. (2005). Essential Tensions: Identity, Control, and Risk in Research. *Social Studies of Science, 35*(5), 787-826.

Hajer, M., & Laws, D. (2018). Ordering through Discourse. In R. Goodin, M. Moran, & M. Rein (Eds.), *The Oxford Handbook of Public Policy.* Oxford University Press.

Hardwig, J. (1985). Epistemic Dependence. *The Journal of Philosophy, 82*(7), 335-349.

Hasan, I., & Tucci, C. L. (2010). The innovation–economic growth nexus: Global evidence. *Research Policy*, 1264-1276.

Haveman, H. A., & Gualtieri, G. (2017). Institutional Logics. In *Oxford Research Encyclopaedia Business and Management.* Oxford University Press. doi: 10.1093/acrefore/9780190224851.013.137

Heinze, T., Shapira, P., Rogers, J., & Senker, J. (2009). Organizational and institutional influences on creativity in scientific research. *Research Policy, 38*, 610-623.

Hendrickx, K., & Van Hoyweghen, I. (2018). Perspective: An Epigenetic Prism to Norms and Values. *Frontiers in Genetics*, 1-5.

Herbert, D., Barnett, A., Clarke, P., & Graves, N. (2013). On the time spent preparing grant proposals: an observational study of Australian researchers. *BMJ Open, 3*. doi:10.1136/bmjopen-2013-002800

Hess, D. (2015). Undone science and social movements. A review and typology. In M. Gross, & L. McGoey (Eds.), *Routledge International Handbook of Ignorance Studies* (pp. 141-154). Routledge.

Hess, D. (2020). The Sociology of Ignorance and Post-Truth Politics. *Sociological Forum*, 241-249.

Hill-Briggs, F., Adler, N., Berkowitz, S., Chin, M., Gary-Webb, T., Navas-Acien, A., . . . Haire-Joshu, D. (2021). Social Determinants of Health and Diabetes: A Scientific Review. *Diabetes Care* , 258-279.

Holland, M. (2018). *Environment Directorate. Socio-economic assessment of phthalates. ENV/WKP(2018)7.* Organisation for Economic Co-operation and Development. http://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=ENV/WKP(2018)7&docLanguage=En

Honkela, N., Toikka, A., Hukkinen, J., & Honkela, T. (2014). Coming to grips with scientific ignorance in the governance of endocrine disrupting chemicals and nanoparticles. *Environmental Science and Policy,* 154-163.

Horne, L. (2019). Public Health, Public Goods and Market Failure. *Public Health Ethics*, 287-292.

Horrobin, D. (1990). The Philosophical Basis of Peer Review and the Suppression of Innovation. *JAMA, 9*, 1438-1441.

Howard, J. (2011). Environmental nasty surprise, post-normal science, and the troubled role of experts in sustainable democratic environmental decision making. *Futures, 43*, 182-195.

Howarth, D., & Griggs, S. (2012). Poststructuralist Policy Analysis: Discourse, Hegemony, and Critical Explanation. In F. Fischer, & H. Gottweis (Eds.), *The Argumentative Turn Revisited* (pp. 305-342). Duke University Press.

HRC. (2018). *Contract for Research Funding: MMH-030225-16-482-V3HRC.* Health Research Council New Zealand.

HRC. (2019). *Making a difference. The Health Research Council Investment Impact Report.* Health Research Council.

HRC. (2020a). *2021 Explorer Grant Application Guidelines 2021.* Health Research Council.

HRC. (2020b). *2021 Project Application Guidelines.* Wellington: Health Research Council. Retrieved from https://gateway.hrc.govt.nz/funding/downloads/2021_Project_Application_Guidelines.pdf

HRC, MBIE, MoH. (2019). *The New Zealand Health Research Prioritisation Framework: Maximising the benefits of health research for New Zealanders.* Health Research Council of New Zealand, the Ministry of Business, Innovation and Employment and the Ministry of Health.

Humpage, L. (2014). *Policy change, public attitudes and social citizenship: Does neoliberalism matter?* Polity Press.

Hunt, J., Schinn, S., Jones, M., & Bundy, B. (2017). Rapid, Portable Detection of Endocrine Disrupting Chemicals Through Ligand-Nuclear Hormone Receptor Interactions. *Analyst*. doi:10.1039/C7AN01540B.

Institute of Medicine. (1988). *The Future of Public Health.* National Academies Press.

Iorns Magallanes, C. (2018). Permitting Poison: Pesticide Regulation in Aotearoa New Zealand. *EPLJ*, 456-490.

Jasanoff, S. (1992). (No?) Accounting for Expertise. *Science and Public Policy*, 157-162.

Jasanoff, S. (1992). Science, politics and the renegotiation of expertise at EPA. *Osiris*, 195-217.

Jasanoff, S. (2004). Ordering Knowledge, Ordering Society. In S. Jasanoff (Ed.), *States of knowledge : the co-production of science and social order* (pp. 14-45). London: Routledge.

Jasanoff, S. (2011). The Practices of Objectivity in Regulatory Science. In C. Camic, N. Gross, & M. Lamont, *Social Knowledge in the Making* (pp. 307-338). The University of Chicago Press.

Jasanoff, S., & Simmet, H. (2017). No funeral bells: Public reason in a 'post-truth' age. *Social Studies of Science*, 751-770.

Jayasinghe, U., Marsh, H., & Bond, N. (2003). A multilevel cross-classified modelling approach to peer review of grant proposals: the effects of assessor and researcher attributes on assessor ratings. *J. R. Statist. Soc., 166*, 279-300.

Jeon, J. (2019). Invisibilizing politics: Accepting and legitimating ignorance in environmental sciences. *Social Studies of Science*, 839-862.

Jin, Y., Sisheng, W., Zeng, Z., & Fu, Z. (2017). Effects of environmental pollutants on gut microbiota. *Environmental Pollution, 222*, 1-9.

Johnson, V. (2020). Gut microbiome composition and diversity are related to human personality traits. *Human Microbiome Journal*.

Jones, D. (2016). Sequencing the exposome: A call to action. *Toxicology Reports, 3*, 29-45.

Kapstein, M. (2019). The Moral Entrepreneur: A New Component of Ethical Leadership. *J Bus Ethics, 156*, 1135-1150.

Karlsson, O., Rocklov, J., Lehoux, A., Bergquist, J., Rutgersson, A., Blunt, M., & Birnbaum, L. (2020). The human exposome and health in the Anthropocene. *International Journal of Epidemiology*, 1-12.

Kassotis, C., Vandenberg, L., Demeneix, B., Porta, M., Slama, R., & Trasande, L. (2020). Endocrine-disrupting chemicals: economic, regulatory, and policy implications. *The Lancet, 8*, 719-730.

Kelsey, J. (1997). *The New Zealand Experiment: A World Model for Structural Adjustment?* . Wellington: Bridget Williams Books.

Kenakin, T. (2009). Ligand-Receptor Binding and Tissue Response. In M. Hacker, W. Messer, & K. Bachmann (Eds.), *Pharmacology Principles and Practice* (pp. 63-74). Academic Press.

King, A. (2001). *The New Zealand Health Strategy.* Ministry of Health.

Knorr-Cetina, K. (1999). *Epistemic Cultures. How the sciences make knowledge.* Harvard University Press.

Krimsky, S. (2000). *Hormonal Chaos: The Scientific and Social Origins of the Environmental Endocrine Hypothesis.* Johns Hopkins University Press.

Krimsky, S. (2003). *Science in the Public Interest: Has the Lure of Profits Corrupted Biomedical Research.* Rowman & Littlefield Publishers.

Krimsky, S. (2014). Low-Dose Toxicology Narratives from the Science-Transcience Interface. In J. Boudia, & N. Jas (Eds.), *Powerless Science? Science and Politics in a Toxic World* (pp. 234-253). Berghahn.

Kuhn, T. (1970). *The Structure of Scientific Revolutions* (4th ed.). University of Chicago Press (2012).

Kumar, M., Sarma, D., Shubham, S., Kumawat, M., Verma, V., Prakash, A., & Tiwari, R. (2020). Environmental Endocrine-Disrupting Chemical Exposure: Role in Non-Communicable Diseases. *Front. Public Health*. doi:https://doi.org/10.3389/fpubh.2020.553850

Kuukkanen, J. (2012). Autonomy and Objectivity of Science. *International Studies in the Philosophy of Science, 26*(3), 309-334.

La Merrill, M. A., Vandenberg, L. N., Smith, M., Goodson, W., Browne, P., Patisaul, H., . . . Zoeller, R. T. (2019). Consensus on the key characteristics of endocrine- disrupting chemicals as a basis for hazard identification. *Endocrinology*, 45-57.

Lamont, M. (2009). *How professors think: Inside the curious world of academic judgement.* Harvard University Press.

Lamoureaux, J. (2019). Reimagining Endocrine Disruption through China's Environmental Hormones. *Cross-Currents: East Asian History and Culture Review*, 78-100.

Landecker, H., & Panofsky, A. (2013). From Social Structure to Gene Regulation, and Back: A Critical Introduction to Environmental Epigenetics for Society. *Annual Review of Sociology*, 333-357.

Landrigan, P., Fuller, R., Hu, H., Caravanos, J., Cropper, M., Hanrahan, D., . . . Suk, W. (2018). Brief Communication: Pollution and Global Health – An Agenda for Prevention. *Environmental Health Perspectives, 126*(8).

Latour, B. (1987). *Science in action: How to follow scientists and engineers through Society.* Open University Press.

Latour, B., & Woolgar, S. (1986). *Laboratory Life. The Construction of Scientific Facts.* University Press.

Laudel, G. (2006). The art of getting funded: how scientists adapt to their funding conditions. *Science and Public Policy*, 489-504.

Laudel, G., & Gläser, J. (2014). Beyond breakthrough research: Epistemic properties of research and their consequences for research funding. *Research Policy*, 1204-1216.

Laudel, G., & Weyer, E. (2014). Where have all the scientists gone? Building research profiles at Dutch Universities and its consequence for research. *42*, 111-140.

Lee, C., Sugimoto, C., Zhang, G., & Cronin, B. (2013). Bias in Peer Review. *J. Assoc. Inf. Sci. Technol, 64*(1), 2-17.

Lee, R., & Mykituik, R. (2018). Surviving difference: Endocrine-disrupting chemicals, intergenerational justice and the future of human reproduction. *Feminist Theory*, 205-221.

Leitch, S., & Davenport, S. (2005). The politics of discourse: Marketization of the New Zealand science and innovation system. *Human Relations*, 891-912.

Leitch, S., Motion, J., Merlot, E., & Davenport, S. (2014). The fall of research and rise of innovation: Changes in New Zealand science policy discourse. *Science and Public Policy*, 119-130.

Leydesdorff, L., & Etzkowitz, H. (1996). Emergence of a Triple Helix of university-industry-government relations. Conference Report. *Science and Public Policy, 23*(5), 279-286.

Li, D. (2017). Expertise versus Bias in Evaluation: Evidence from the NIH. *Am. Econ. J, 9*(2), 60-92.

Li, D., Azoulay, P., & Sampat, B. (2017). The applied value of public investments in biomedical research. *Science, 356*(6333), 78-81.

Lillie-Blanton, M., & Laveist, T. (1996). Race/ethnicity, the social environment, and health. *Social Science & Medicine, 43*, 83-91.

Long, J., & Fox, M. (1995). Scientific Careers: Universalism and Particularlism. *Annu. Rev. Sociol., 21*, 45-71.

Lovell, S., Kearns, R., & Prince, R. (2014). Neoliberalism and the contract state: exploring innovation and resistance among New Zealand Health Promoters. *Critical Public Health*, 308-320. doi:10.1080/09581596.2013.808317

Ludden, T. (1991). Nonlinear pharmacokinetics clinical Implications. *Clin Pharmokinet, 20*(6), 429-446.

Lundvall, B. (2016). *The Learning Economy and the Economics of Hope.* London: Anthem Press.

MacKay, K., & Quigley, M. (2018). Exacerbating Inequalities? Health Policy and the Behavioural Sciences. *Health Care Anal, 26*, 380-397.

Maglaughlin, K., & Sonnenwald, D. (2005). Factors that Impact Interdisciplinary Natural Science Research Collaboration in Academia. *International Society for Scientometrics and Informatrics (ISSI) 2005 Conference.* Stockholm,: 1-12.

Marmot, M. (2018). Medical Care, Social Determinants of Health, and Health Equity. *World Medical and Health Policy*, 195-197.

MBIE & MOH. (2015). *Strategic Refresh of the Health Research Council*. Wellington: Ministry of Business, Innovation and Employment & Ministry of Health.

MBIE & MoH. (2017). *New Zealand Health Research Strategy.* The Ministry of Business, Innovation and Employment and the Ministry of Health.

MBIE. (2015). *National Statement of Science Investment 2015-2025.* Ministry of Business, Innovation and Employment.

MBIE. (2016). *Review of Crown Research Institute Core Funding.* Ministry of Business, Innovation & Employment.

MBIE. (2018). *Research, Science and Innovation System Performance Report.* Ministry of Business Innovation and Employment.

MBIE. (2019a). *The Impact of Research. Position Paper.* Ministry of Business, Innovation & Employment.

MBIE. (2019b, September). *New Zealand's Research, Science and Innovation Strategy: Draft for Consultation. September 2019.* Ministry of Business, Innovation and Employment (MBIE). Retrieved from https://www.mbie.govt.nz/dmsdocument/6935-new-zealands-research-science-and-innovation-strategy-draft-for-consultation

MBIE. (2020a). *Briefing for the Incoming Minister of Research, Science and Innovation.* Wellington: Ministry of Business, Innovation & Employment.

MBIE. (2020b). *Who We Are*. Retrieved 10 8, 2020, from Ministry of Business Innovation & Employment: https://www.mbie.govt.nz/about/who-we-are/

McCartney, G., Hearty, W., Arnot, J., Popham, F., Cumbers, A., & McMaster, R. (2019). Impact of Political Economy on Population Health: A Systematic Review of Reviews. *APJH, 109*(6).

McEwan, B., & Seeman, T. (1999). Protective and Damaging Effects of Mediators of Stress Elaborating and Testing the Concepts of Allostasis and Allostatic Load. *Annals of the New York Academy of Sciences, 896*(1), 30-47.

Mendoza, P., Kuntz, A., & Berger, J. (2012). Bourdieu and Academic Capitalism: Faculty "Habitus" in Materials Science and Engineering. *The Journal of Higher Education*, 558-581.

Merton, R. (1942). The Normative Structure of Science. In N. Storer (Ed.), *The Sociology of Science Theoretical and Empirical Investigations.* The University of Chicago Press.

Merton, R. (1957). Priorities in Scientific Discovery: A Chapter in the Sociology of Science. *American Sociological Review*, 635-659.

Merton, R. (1979). The Matthew Effect in Science. In R. Merton, *The Sociology of Science. Theoretical and Empirical Investigations* (pp. 439-459). The University of Chigago Press.

Mesnage, R., Benbrook, C., & Antoniou, M. (2019). Insight into the confusion over surfactant co-formulants in glyphosate-based. *Food and Chemical Toxicology, 128*, 137-145.

Michaels, D. (2020). *The Triumph of Doubt. Dark Money and the Science of Deception.* Oxford University Press.

Millar, E., Dowell, A., Lawrenson, R., Mangin, D., & Sarfati, D. (2018). Clinical guidelines: what happens when people have multiple conditions. *NZMJ*, 73-81.

Minister of Health. (2016). *New Zealand Health Strategy.* Ministry of Health.

Minson, J. (2012). The Cost of Collaboration: Why Joint Decision Making Exacerbates Rejection of Outside Information. *Psychological Science*, 1-6. doi:. http://dx.doi.org/0.1177/0956797611429132

MoH & MBIE. (2019). *New Zealand Health Research Strategy Action One: National Priority Setting. Summary of submissions and consultation. March 2019* . Ministry of Health and the Ministry of Business, Innovation and Employment.

MoH. (2018). *Health and Independence Report 2017. The Director-General of Health's Annual Report on the State of Public Health.* Ministry of Health.

Moore, K., Kleinman, D., Hess, D., & Frickel, S. (2011). Science and neoliberal globalization: a political sociological approach. *Theoretical Sociology, 40*, 505-532.

Moore, S., Neylon, C., Eve, M., O'Donnell, D., & Pattinson, D. (2016). “Excellence R Us”: university research and the fetishisation of excellence. *Palgrave Communications*. doi: 10.1057/palcomms.2016.105

Morello-Frosch, R., Zuk, M., Jerrett, M., Shamasunder, B., & Kyle, A. (2011). Understanding the Cumulative Impacts of Inequalities in Environmental Health: Implications for Policy. *Health Affairs*, 879-887.

Morens, D., Folkers, G., & Fauci, A. (2004). The challenge of emerging and re-emerging infectious diseases. *Nature, 430*, 242-249.

Morris, N. (2010). Authority Relations as Condition for, and Outcome of, Shifts in Governance. In R. Whitley, J. Gläser, & L. Engwall (Eds.), *Reconfiguring Knowledge Production: Changing Authority Relationships in the Sciences and their Consequences for Intellectual Innovation.* Oxford Scholarship Online.

Mosca, A., Leclerc, M., & Hugot, J. (2016). Gut Microbiota Diversity and Human Diseases: Should We Reintroduce Key Predators in Our Ecosystem? *Frontiers in Microbiology, 7*.

Muller, R. (1980). Innovation and Scientific Funding. *Science, 209*(4459), 880-883.

Murphy, K., & Topel, R. (Eds.). (2003). *Measuring the gains from medical research an economic approach.* Chicago: University of Chicago School.

Murray, D., Siler, K., Larivière, V., Chan, W., Collings, A., Raymond, J., & Sugimoto, C. (2019). Author-Reviewer Homophily in Peer Review. *bioRxiv*. doi:doi: https://doi.org/10.1101/400515

Nader, L. (1997). Sidney W. Mintz for 1995: Controlling Processes Tracing the Dynamic Components of Power. *Current Anthropology, 38*(5), 711-738.

Navarro, V. (2009). What we mean by the social determinants of health. *International Journal of Health Services, 39*(3), 423-441.

Newton, M., Farrelly, T., & Sinner, J. (2020). Discourse, agency, and social license to operate in New Zealand's marine environment. *Ecology and Society, 25*(1).

NIEHS. (2020, November 17). *Endocrine Disruptors*. Retrieved January 22, 2021, from National Institute of Environmental Health Sciences: https://www.niehs.nih.gov/health/topics/agents/endocrine/index.cfm

Norman, R., Carpenter, D., Scott, J., Brune, M., & Sly, P. (2013). Environmental exposures: an underrecognized contribution to noncommunicable diseases. *Rev Environ Health*, 59-65.

Norouzitallab, P., Baruah, K., Vanrompay, D., & Bossier, P. (2019). Can epigenetics translate environmental cues into phenotypes? *Science of the Total Environment*, 1281-1293.

Nowak, K., Jabłońska, E., & Ratajczak-Wrona, W. (2019). Immunomodulatory effects of synthetic endocrine disrupting chemicals on the development and functions of human immune cells. *Environment International, 125*, 350-364.

Nowotny, H., Scott, P., & Gibbons, M. (2003). Re-Thinking Science: Mode 2 in Societal Context*). https://users.dcc.uchile.cl/~cgutierr/cursos/cts/articulos/Mode2-Science-Gibbons-Nowotny.pdf

NSC. (2019). *A Better Start. Future Strategy 2019-2024.* The University of Auckland.

Nussbaum, M., & Sen, A. (1993). *The Quality of Life.* Oxford: Clarendon Press.

O'Campo, P., & Dunn, J. (Eds.). (2012). *Rethinking Social Epidemiology. Towards a Science of Change.* New York: Springer.

OECD. (2005). *The Measurement of Scientific and Technological Activities, Oslo Manual:Guidelines for Collecting and Interpreting Innovation Data, 3rd edition,.* A joint publication of OECD and Eurostat.

OECD. (2016). *OECD Science, Technology and Innovation Outlook.* Organisation for Economic Cooperation and Development.

OECD. (2018). *Oslo Manual. Guidelines for collecting, reporting, and using data on innovation.* OECD Publishing.

OECD. (2019). *The Heavy Burden of Obesity. The economics of prevention. OECD Health Policy Studies.* OECD Publishing. doi:https://doi.org/10.1787/67450d67-en.

Oreskes, N., & Conway, E. (2010). *Merchants of Doubt.* Bloomsbury Press.

Ostlin, P., Schrecker, T., Sadana, R., Bonnefoy, J., Hertzman, C., Kelly, M., . . . Vaghri, Z. (2011). Priorities for Research on Equity and Health: Towards an Equity-Focused Health Research Agenda. *PLoS Medicine, 8*(11), e1001115.

Ottersen, O., Dasgupta, J., Blouin, C., Buss, P., Chongsuvivatwong, V., Frenk, J., . . . Scheel, I. (2014). The political origins of health inequity: prospects for change. *The Lancet*, 630-667.

PCO. (1956). *Health Act 1956. 3a Function of the Ministry.* Parliamentary Counsel Office.

PCO. (1990). *Foundation for Research, Science, and Technology Act 1990.* Parliamentary Counsel Office.

PCO. (2010). *Research, Science, and Technology Act 2010.* Parliamentary Counsel Office.

PCO. (2014). *Health Research Council Act 1990.* Parliamentary Counsel Office. http://www.legislation.govt.nz/act/public/1990/0068/latest/DLM213017.html

Pearce, N. (1996). Traditional Epidemiology, Modern Epidemiology, and Public Health. *American Journal of Public Health,* 679-683.

Peck, J. (2010). Neoliberalizing states: thin policies/hard outcomes. *Progress in Human Geography,* 445-455.

Penny, S., & Carryer, J. (2011). Obesity and health—new perspectives from bioscience research suggest directions for clinical practice. *NZMJ,* 73-82.

Philpot, K., Dooley, L., O'Reilly, C., & Lupton, G. (2011). The Entrepreneurial University: Examining the Underlying Tensions. *Technovation, 31*(4), 161-170.

Picotti, P., Bodenmiller, B., & Aebersold, R. (2013). Proteomics meets the scientific method. *Nature Methods, 10*, 24-27.

Pinto, M., & Hicks, D. (2019). Legitimizing Values in Regulatory Science (Commentary). *Environmental Health Perspectives,* 35001-1-8.

Plamondon, K., Bottorff, J., Caxaj, C., & Graham, I. (2020). The integration of evidence from the Commission on Social Determinants of Health in the field of health equity: a scoping review. *Critical Public Health, 30*(4), 415-428.

Popp Berman, E. (2012). Explaining the move toward the market in US academic science: how institutional logics can change without institutional entrepreneurs. *Theor Soc, 41*, 261-299.

Popp Berman, E. (2014). Not just neoliberalism: economization in US science and technology policy. *Science, Technology, & Human Values, 39*(3), 397-431.

Porcher, R., Kovanis, M., Ravaud, P., & Trinquart, L. (2016). The Global Burden of Journal Peer Review in the Biomedical Literature: Strong Imbalance in the Collective Enterprise. *PLOS One*.

Prince, R., Kearns, R., & Craig, D. (2006). Governmentality, discourse and space in the New Zealand health care system, 1991–2003. *Health & Place, 12*, 253-266.

Prochaska, J., Nolen, A., Kelley, H., Sexton, H., Linder, S., & Sullivan, J. (2014). Social Determinants of Health in Environmental Justice Communities. *Hum Ecol Risk Assess.*, 980-994.

Proctor, R. (1991). *Value-Free Science? Purity and Power in Modern Knowledge.* Cambridge: Harvard University Press.

Proctor, R. (1995). *Cancer Wars. How Politics Shape What We Know and Don't Know About Cancer.* Basic Books.

Prüss-Ustün, A., Wolf, J., Corvalán, C., Neville, C., Bos, R., & Neira, M. (2016). Diseases due to unhealthy environments: an updated estimate of the global burden of disease attributable to environmental determinants of health. *Journal of Public Health*, 464-475.

Rappaport, S. (2016). Genetic Factors Are Not the Major Causes of Chronic Diseases. *PLoS One*, e0154387.

Rappaport, S. (2018). Redefining environmental exposure for disease etiology. *Systems Biology and Applications, 4*(30).

Rappaport, S., & Smith, M. (2010). Environment and Disease Risks. *Science* , 460-461.

Ravetz, J. (2011). Postnormal Science and the maturing of the structural contradictions of modern European science. *Futures, 43*, 142-148.

Rayner, S. (2012). Uncomfortable knowledge: the social construction of ignorance in science and environmental policy discourses. *Economy and Society, 41*(1), 107-125.

Reich, M. (2019). Political economy analysis for health. *Bull World Health Organ*. doi:http://dx.doi.org/10.2471/BLT.19.238311

Reid, I., Joyce, P., Fraser, J., & Crampton, P. (2014). Government funding of health research in New Zealand. *NZMJ, 127*(1389), 25-30.

Rip, A. (2011). Protected Spaces of Science: Their Emergence and Further Evolution in a Changing World. In M. Carrier, & A. Nordmann (Eds.), *Science in the Context of Application* (pp. 197-220). Springer.

Risbridger, G. P. (2015). Editorial: The Future of Our Basic Science and Scientists. *Mol Endocrinol*, 1673-1674. doi:doi: 10.1210/me.2015-1284

Rissman, E., & Adli, M. (2014). Minireview: Transgenerational Epigenetic Inheritance: Focus on Endocrine Disrupting Compounds. *Endocrinology*, 2770-2780.

Roa, T., Beggs, J., Williams, J., & Moller, H. (2009). New Zealand's Performance Based Research Funding (PBRF) model undermines Maori research. *Journal of the Royal Society of New Zealand*, 233-238.

Robertson, T., & Farrelly, T. (2015). Bisphenol A (BPA) exposure in New Zealand: a. *Journal of the Royal Society of New Zealand, 45*(4), 184-196.

Roebber, P., & Schultz, D. (2011). Peer Review, Program Officers and Science Funding. *PLOS One*, e18680.

Rosen, G. (1958). *A history of public health.* MD Publications.

Roy, R. (1985). Funding Science: The Real Defects of Peer Review and an Alternative to it. *Science, Technology, & Human Values*, 73-81.

Ruiz, D., Becerra, M., Jagai, J., Ard, K., & Sargis, R. (2018). Disparities in Environmental Exposures to Endocrine-Disrupting Chemicals and Diabetes Risk in Vulnerable Populations. *Diabetes Care*, 193-205.

Rushforth, A., Franssen, T., & de Rijcke, S. (2018). Portfolios of Worth: Capitalizing on Basic and Clinical Problems in Biomedical Research Groups. *Science, Technology, & Human Values, 44*(2), 209-236.

Russell, J., Grant, C., & Morton, S. (2019). Multimorbidity in Early Childhood and Socioeconomic Disadvantage: Findings From a Large New Zealand Child Cohort. *Academic Pediatrics, 20*(7), P619-627.

Russell, L., & Sinha, A. (2016). Strengthening Cost-Effectiveness Analysis for Public Health Policy. *Am J Prev Med, 50*(5S1), S6-S12.

Scheringer, M., Strempel, S., Hukari, S., Ng, C., Blepp, M., & Hungerbuhler, K. (2012). How many persistent organic pollutants should we expect? *Atmospheric Pollution Research, 3*, 383-391.

Schmeller, D., Courchamp, F., & Killeen, G. (2020). Biodiversity loss, emerging pathogens and human health risks. *Biodiversity and Conservation* , 3095-3102.

Schot, J., & Steinmueller, W. (2018). Three frames for innovation policy: R&D, systems of innovation and transformative change. *Research Policy*, 1554-1567.

Schrecker, T. (2018). The Political Economy of Public Health: Challenges for Ethics. In A. Mastroianni, J. Kahn, & N. Kass, *The Oxford Handbook of Public Health Ethics* (pp. 1-17). Oxford Handbooks Online.

Schrecker, T., & Bambra, C. (2015). *How Politics Makes Us Sick. Neoliberal Epidemics.* Palgrave Macmillan.

Schug, T., Johnson, A., Birnbaum, L., Colborn, T., Guillette, L., Crews, D., . . . Heindel, J. (2016). Minireview: Endocrine Disruptors: Past Lessons and Future Directions. *Molecular Endocrinology*, 1096.

Schumpeter, J. (1943). *Capitalism, Socialism and Democracy.* Routledge.

Sengupta, J. (2014). *Theory of Innovation. A New Paradigm of Growth.* Dordrecht: Springer.

SFU. (2010). *A History of Government-funded Science from 1865–2009. Report 9a 2058.* Wellington: The Sustainable Future Institute.

Shore, C. (2015). 'After neoliberalism'? The reform of New Zealand's university system. In *Learning Under Neoliberalism: Ethnographies of Governance in Higher Education* (pp. 30-49). Oxford: Berghahn.

Shore, D., & Davidson, M. (2014). Beyond collusion and resistance Academic–management relations within the neoliberal university. *Learning and Teaching, 7*(1), 12-28.

Shrader-Frechette, K. (2011). Taking action on developmental toxicity: Scientists' duties to protect children. *Environmental Health*.

Sigl, L. (2016). On the Tacit Governance of Research by Uncertainty: How Early Stage Researchers Contribute to the Governance of Life Science Research. *Science, Technology, & Human Values*, 347-374.

Skinner, M. (2016). Epigenetic transgenerational inheritance. *Endocrinology, 12*.

Slaughter, R. (2012). Welcome to the anthropocene. *Futures, 44*, 119-126.

Slaughter, S., & Leslie, L. (1997). *Academic Capitalism.* Johns Hopkins University Press.

Smith, A. (1776). *An Inquiry into the Nature and Causes of the Wealth of Nations.* W. Strahan and T. Cadell.

Solecki , R., Kortenkamp, A., Bergman, A., Chahoud, I., Degen, G., Dietrich, D., . . . Boobis, A. (2017). Scientific principles for the identification of endocrine-disrupting chemicals: a consensus statement. *Archives of Toxicology, 91*(2), 1001-1006.

Stark, L. (2014). Declarative Bodies. In D. Kleinman, & K. Moore, *Routledge Handbook of Science, Technology, and Society* (pp. 437-455). Routledge.

Steffen, W., Richardson, K., Rockstrom, J., Cornell, S. E., Fetzer, I., Bennett, E. M., . . . Persson, L. M. (2015). Planetary boundaries: Guiding human development on a changing planet. *Science*.

Stensaker, B., & Benner, M. (2013). Doomed to be Entrepreneurial: Institutional Transformation or Institutional Lock-Ins of 'New' Universities? *Minerva*, 399-416.

Stern, S., Porter, M., & Furman, J. (2000). *The Determinants of National Innovation Capacity.* National Bureau of Economic Research.

Stiglitz, J. (2013). *The Price of Inequality: How Today's Divided Society Endangers Our Future.* . W.W. Norton & Company.

Stirling, A., & Gee, D. (2002). Science, Precaution and Practice. *Public Health Reports, 117*, S21-S33.

Strathern, M. (1997). The Work of Culture: An Anthropological Perspective. In A. Clarke, & E. Parsons (Eds.), *Culture, Kinship and Genes: Towards a Cross Cultural Genetics* (pp. 40-53). Macmillan Press.

Sundin, J. (2019). Public Health is Politics. *Interchange*, 129-136.

Susser, M. (1985). Epidemiology in the United States after World War II: The evolution of technique. *Epidemiologic Reviews, 7*, 147-177.

Swinburn, B. A., Kraak, V. I., Allender, S., Atkins, V., Baker, P., Bogard, J., . . . Friel, S. (2019). The Global Syndemic of Obesity, Undernutrition, and Climate Change: The Lancet Commission report. *The Lancet*, 791-846.

TEC. (2020, May 13). *Centres of Research Excellence (CoREs) selection process.* Tertiary Education Commission Te Amorangi Mātauranga Matua. https://www.tec.govt.nz/assets/Forms-templates-and-guides/d245f6692c/ToR-for-CoREs-selection-2019_20.pdf

Tenbensel, T., Cumming, J., Ashton, T., & Barnett, P. (2008). Where there's a will, is there a way?: Is New Zealand's publicly funded health sector able to steer towards population health? *Social Science & Medicine, 67*, 1143-1152.

The Lancet. (2019). Editorial: Global health: time for radical change? *The Lancet*, 1129. The Lancet. https://www.download.thelancet.com/gbd

The Marmot Review. (2010). *Fair Society, Healthy Lives. Strategic Review of Health Inequalities in England post-2010.* The Marmot Review.

The Treasury. (2020). *The Estimates of Appropriations 2020/21 - Economic Development and Infrastructure Sector B.5 Vol.1* . The Treasury, New Zealand Government.

Tilg, H., & Moschen, A. (2016). Food, Immunity and the Microbiome. *Gastroenterology*, 1107-1119.

Travis, G., & Collins, H. (1991). New light on old boys: cognitive and institutional particularism in the peer review system. *Science, Technology and Human Values*, 322-341.

Treasury. (2020a). *Vote Business, Science and Innovation. The Estimates of Appropriations 2020/21 - Economic Development and Infrastructure Sector B.5 Vol.1.* The Treasury.

Treasury. (2020b). *Vote Tertiary Education. The Estimates of Appropriations 2020/21 - Education and Workforce Sector B.5 Vol.2.* The Treasury.

UCL. (2013). *Review of social determinants and the health divide in the WHO European Region: final report.* World Health Organization.

UNEP. (2019). *Global Chemicals Outlook II: From Legacies to Innovative Solutions. Implementing the 2030 agenda for sustainable development.* United Nations Environment Program.

Upton, S. (1991). *Health Policy: Your Health and the Public Health.* Ministry of Health.

van Rijnsoever, F., & Hessels, L. (2010). Factors associated with disciplinary and interdisciplinary research collaboration. *Research Policy*, 463-472.

Vandenberg, L. (2019). Endocrine Disruptors and Other Environmental Influences on Hormone Action. In L. Welling, & T. Shackelford, *The Oxford Handbook of Evolutionary Psychology and Behavioral Endocrinology* (pp. 1-36). Oxford Handbooks Online. doi:10.1093/oxfordhb/9780190649739.013.

Vermeulen, R., Schymanski, E., Barabási, A., & Miller, G. (2020). The exposome and health: Where chemistry meets biology. *Science*, 392-396.

vom Saal, F., & Vandenberg, L. (2020). Update on the health effects of bisphenol A: Overwhelming evidence of harm (Accepted manuscript). *Endocrinology*.

Wang, J., Lee, Y., & Walsh, J. (2018). Funding model and creativity in science: Competitive versus block funding and status contingency effects. *Research Policy*, 1070-1083.

Weaver, J. (2021, January 05). *Endocrine disruptor identification begins with biology.* Environmental Factor. https://factor.niehs.nih.gov/2019/12/feature/1-feature-endocrine-disruptor/index.htm

Weber, M. (1978). *Economy and society: An outline of interpretative sociology.* (G. Roth, & C. Wittich, Eds.) University of California Press.

Whitley, R. (1984). *The intellectual and social organization of the sciences.* Oxford: Clarendon.

Whitley, R. (2010). Reconfiguring the Public Sciences. In R. Whitley, J. Gläser, & L. Engwall (Eds.), *Reconfiguring Knowledge Production: Changing Authority Relationships in the Sciences and their Consequences for Intellectual Innovation* (pp. 1-50). Oxford Scholarship Online.

Whitley, R., Gläser, J., & Laudel, G. (2018). The Impact of Changing Funding and Authority Relationships on Scientific Innovations. *Minerva*, 109-134.

WHO. (2020). *International Clinical Trials Registry Platform (ICTRP)*. October 1, 2020, from World Health Organization: https://www.who.int/ictrp/en/

WHO CSDH. (2008). *Closing the gap in a generation: Health equity through action on the social determinants of health. Final Report of the Commission on Social Determinants of Health.* Geneva: World Health Organization.

WHO UNEP. (2012). State of the Science of Endocrine Disrupting Chemicals. In A. Bergman, J. J. Heindell, S. Jobling, K. Kidd, & R. T. Zoeller (Eds.). Geneva: World Health Organization, United Nations Environment Programme:.

Wild, C. (2005). Complementing the genome with an ‘exposome’: the outstanding challenge of environmental exposure measurement in molecular epidemiology. *Cancer Epidemiol Biomarkers Prev*, 1847-1850.

Wild, C. (2012). The exposome: from concept to utility. *International Journal of Epidemiology*, 24-32.

Woodhouse, E., & Howard, J. (2009). Stealthy Killers and Governing Mentalities: Chemicals in Consumer Products. In M. Singer, & H. Baer, *Killer commodities; public health and the corporate production of harm* (pp. 35-66). AltaMira Press.

Woolf, S. (2008). Commentary: The Meaning of Translational Research and Why It Matters. *JAMA*, 211-213.

Wynne, B. (1992). Misunderstood misunderstanding: social identities and public uptake of science. *Public Understand. Sci*(1), 281-304.

Zhao, L., Zhou, S., & Gustafsson, J. (2019). Nuclear Receptors: Recent Drug Discovery for Cancer Therapies. *Endocrine Reviews, 40*(5), 1207-1249.

Zoeller, R., Brown, T., Doan, L., Gore, A., Skakkebaek, N., Soto, A., . . . Vom Saal, F. (2012). Endocrine-disrupting chemicals and public health protection: A statement of principles from the Endocrine Society. *Endocrinology, 153*(9), 1422.