OFFICE OF THE PRIME MINISTER'S CHIEF SCIENCE ADVISOR

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NEW TECHNOLOGIES AND SOCIAL CONSENSUS[1]

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Thank you for the opportunity to speak at this meeting.

I am a member of the OECD Science, Technology and Innovation Advisory Group. And in our discussions, we have repeatedly returned to the question of the social acceptance or otherwise of new technologies: whether we're talking about the digital, engineering or biological technologies. Whenever disruptive technologies appear, then the issue of social licence is likely to emerge and it will be largely the nature of the response of the community, either deliberatively (as in the case of some regulated innovations such as new pharmaceuticals) or by the force of the market that determines which technologies are used and which are not.

This is nothing new.

We can go back to perhaps the first real example of a contentious and complex interaction between biotechnology and society; the development of margarine. A quote from those times from the anti-margarine (dairy) lobby reads "as for butter vs margarine, I trust cows more than chemists." And, I think, you could think about echoes of that kind of comment in some of the debates that are continuing today about genetically modified foods. The story of margarine suggests that this type of debate, which we might think of as new, has been going on for 150 years. I am indebted for this story to the outstanding recent book by Callestous Juma; *Innovation and Its Enemies (Oxford 2016).*

Through much of 19th century the quality of dairy products was very unreliable and not industrially produced. In the 1860s in France there was concern about the weakness of their military personnel and it was considered to be the result of poor nutrition and inadequate energy intakes. This was driven by the Franco-Prussian wars of that era. And so the French government had an innovation competition (government based innovation contests are not a 21st century invention) for a better form of nutrition for young males and the result of that was the invention of margarine as an animal fat extract. And relatively soon after that American companies started to manufacture margarine from animal fat on an industrial scale. At that time the dairy industry in America was weak and disorganised and quality control was non-existent. The arrival of animal fat based margarine was the impetus that led the dairy

[1] This is the text of my keynote address to the 17th International Biotechnology Symposium in Melbourne October 2017

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industry in the United States to organise, to coalesce and to create lobby groups. The dairy lobby started to provide and promote anti-margarine information and some of this information was based on fraudulent science, on bad science, and on post-truth claims about how poisonous animal fat-based margarine was. Lobbying of farm state politicians across the USA led to the imposition of all sorts of taxes, restrictions on the colour the margarine could be, composition labelling to try to discourage purchase etc.

The anti-margarine advocates had argued that this stuff was full of poisons alleging that it was made from rancid meat. The margarine makers responded with innovation; they found a way to hydrogenate vegetable fats, allowing the margarine manufacturers to move from animal fat to vegetable fat. The vegetable fat they originally used was coconut oil, imported from the Philippines. So then a whole lot of new arguments arose on spurious grounds to stop the importation of Philippine coconut oil. So then the margarine manufacturers started to move to hydrogenating US based soya bean and cotton oils. Now the local politicians had cropping farmers who actually wanted a vegetable fat-based margarine and the power of the dairy lobby started to fall away. Gradually the restrictions evaporated, but it wasn't until the 1970s that in many states margarine first became fully available, without any restrictions. I can remember when in 1972 we stopped having to have a prescription to be able to get margarine in New Zealand. And the argument did not stop overnight. It continued with a more solid and new concern about trans-fats but these were then removed from margarine and it is generally accepted now that lower-fat margarines are healthy products and their widespread use has been suggested to have contributed to the decline of cardiovascular disease.

Think about it: we now find this story somewhat familiar: strong commercial interests in place, impacts on society that led to the organisation of new industry lobbies, all sorts of objections by lobby groups, false science claims put forward, new innovation to overcome the objections which in turn led to new objections. In short it was highly politicised, legal restrictions were imposed, and it took approximately 100 years for social licence to be achieved as the political and social dynamics changed and the alleged risks fell away.

So what is social licence? Social licence is a concept originally developed within industry to allow industries with manufacturing plants to have on-going approval from the local community and other stakeholders. For instance this might relate to operating a chemical plant or a mine. But the social licence concept has now been more broadly adopted to include the acceptance of technological innovations by society and that's going to be the context in which these comments are made. It is a complex topic involving different perceptions of risk and benefit, different views of different stakeholders, it varies for different types of technology and is managed differently for different types of product. Depending on the technology and the societal response, it may involve regulators and formal processes, it engages politicians or it is driven by the market place. In general much attention has been paid in recent years to the life science technologies but there are emergent issues in engineering and digital technologies, some which I have discussed recently[2].

[2] http://www.pmcsa.org.nz/wp-content/uploads/DES-Commentary-.pdf

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Social licence or perhaps better-termed social consensus is rooted in the beliefs and perceptions of those of the local population and is therefore effectively a permission granted by communities. It's also non-permanent and dynamic, because opinions and perceptions are subject to change. While social licence for an industrial plant can be a process which is very formal and can be put forward as part of a planning process, the issue for biotechnologies in particular and for technologies in general is much more complex.

There are many reasons why there are tensions about innovations. But as Juma points out, underneath there is conflict that arises because fundamentally people are comfortable with what they've got, what they know, and generally they fear the unknown. This leads them to prefer what they have despite its limitations, to what might come. And there's always a tension in any society between the stability of what we know now and the novelty of the future and of new innovations. This is a leading source of both public controversy and policy challenges. It is of course exacerbated by many other issues; the positioning and power of incumbent technologies, perceptions of risk[3], costs and benefits of new technology and who receives or bears them, differing world views and so forth. And there can be strong economic interests on either side of such debates. That partisan politics might aggravate such complex discussions is thus almost inevitable. Social licence in this broader context is about when the socio-political environment allows the technology to be used. Many factors affect technological social licence, and the table below is not a complete list but gives a number of considerations.

Many factors affect technological social license

- The relationship between science and society
- The state of evidence
- Fitness for purpose

- Trust in the actors
- World views and disputed values
- Comfort with the old, fear of change
  - Competition with incumbency
  - Concepts of risk and precaution
- Perceptions of cost and benefit

- Economic dimensions
- Vested interests of particular stakeholders
- Politics

- Cultural factors
  - Spiritual beliefs
  - Way of life
- Societal structure and culture

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[3] http://www.pmcsa.org.nz/wp-content/uploads/PMCSA-Risk-paper-2-Nov-2016-.pdf

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Firstly and central to technological acceptance, or not, is the relationship between science and society. There is the issue of the state of the evidence and the claims around it, and this can be the source of real or apparent debate. But underneath this you come down to a set of deeper issues; is there trust in the actors, is there trust in the science? We now hear a lot of the term 'post-trust' society: a key strategy for groups who take a strong position to undermine the credibility of those actors who take an alternate position.

Secondly, people have different worldviews and values and these are often in dispute: science alone cannot not resolve such disputed values. As mentioned above, the underlying human characteristic of comfort with the old and wariness of the new leads to a variety of challenges. Related to this is the issue of competition with incumbent technologies and, in general, if they involve different stakeholders to the new technology, the incumbents will react against it (the dairy farmers reacted against the margarine manufacturer).

In general people accept a new innovation more readily if they can see direct benefit from it, for instance the smartphone, and are less likely to accept a new technology if they think that they're going to pay the cost and take the risk while some other entity like a large pharma company is going to gain the benefit. In all of this there are many different economic dimensions and there can be many different vested interests of particular stakeholders.

There's also a set of cultural factors that are particularly relevant to biotechnology (and perhaps increasingly with some digital technologies as the sense of personal autonomy is threatened). Some technologies such as the use of embryonic stem cells challenge spiritual beliefs. But an often ignored but critical set of cultural factors is fear of impacts on the way of life. I was recently told of a European meeting of wine growers to discuss the issue of organic versus genetically modified grapes. The major objections were not economic, they weren't even about 'interfering with nature', it was simply that the technology might disrupt the normal way of farming and wine growing that had gone on, and created a valued and intimate sub-culture around wine growing: it was the fear of change to that culture which drove their objections. This issue of societal structure and culture is quite deep. Juma, in a whimsical way, describes these issues:

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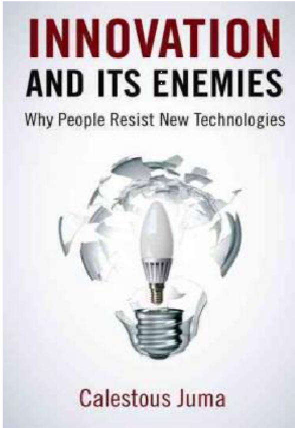
The challenge of innovation

- In the US products are safe until proved risky
- In France products are risky until they are proven safe
- In the UK products are risky even when they are proven safe
- In India products are safe even when proven risky
- In Canada products are neither safe nor risky
- In Japan products are either safe or risky
- In Brazil products are both safe and risky
- In sub-Saharan Africa products are risky even if they do not exist



And while this is somewhat satirical, there is a serious point being made in that different societies do react in very different ways to innovation based on their fundamental world-view as society. This is exemplified by the on-going differences in the way Europe versus the United States are talking about and using gene modification and gene editing.

We frequently refer to 'values' in this type of discussion yet there are different kinds of value. Let's not pretend that science is values-free, there are values in play throughout the scientific process. But the values within science are largely distinct from those of society, although we as individual scientists also share societal values and these in turn, must influence how we perform. Clearly science relies on critical thinking, and is based on institutionalised scepticism and with this, we have ethical standards about what we do and how we do it. And many of the scientific processes are about removing our inherent biases in the collection and analysis of data. The biggest values judgement we all make as scientists is a judgement as to the quality of the evidence and the sufficiency of evidence – is it enough to draw some particular conclusion about a technology or a scientific finding? It is in this area that many of the debates in science can arise. There can be debate between those that think there is enough evidence to come to a certain conclusion and those that do not. And we should be honest and admit that there's nearly always an inferential gap between what we know and what we conclude in science[4].

On the other hand, when considering values in relationship to developing a societal consensus, we are talking about things and issues well beyond such scientific considerations (although the debate may be still framed as scientific). A societal consensus must be achieved

[4] See Heather Douglas's book *Science, Policy and the Value Free I*deal; 2009

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within the frame of a diversity of values and worldviews that we value within a democracy. We must consider the variety of cultural, political and religious values and the different ways we see ourselves in relationship to the planet and to other people. We need to acknowledge the inherent biases we develop from past experience and the broader range of our cognitive biases.

These considerations influence our perceptions of risk and at the heart of social licence are issues around the assessment of risk. The challenge here is that risk means different things to different people. Many scientists are used to presenting risk in an actuarial sense; for example we're talking about 1 in 1000 chances of this happening or 1 in a million chances of that, or a one in a hundred year risk of a major earthquake (which does not mean it could not happen tomorrow). But, most people don't think in those terms especially when thinking about technologies. In short their perceptions of risk are much more subjective[5].

These unconscious biases make us more likely or less likely to assess a particular situation as risky or not. And closely related are our considerations of gain and losses, benefits and burdens. You have a different sense of risk if you think you're going to benefit from a particular technology immediately, compared to if you think you're going to lose. So, if you were a manager at a biotechnology company inventing a genetically modified plant 30 years ago, your perception of risk is likely to have been different to somebody who is not a shareholder in the company and could not see that the technology was going to produce a product that would bring any benefit to them. If you analyse many things that have been controversial, such as margarine or the drilling of off-shore oil wells, or the introduction of various other technologies, you can see these issues of gain and loss, benefit and burden, coming up time and time again in the conversation.

And in a democracy, we need to remember that politicians have a different driver of their perception of risk; it's what happens in the ballot box in 1, 2 or 3 years' time. And yet they must ultimately make regulatory decisions, so you can see that from science to society to our political representation, 'risk' has different implications.

Related to this is our understanding of precaution. Simply put, the precautionary principle was never intended to say you can't do something unless it's absolutely proven to be safe. The nature of the scientific method means that one can never absolutely prove anything to be completely safe. Such a proposition is largely a non-scientific concept beyond mathematics - absolute-proof. Consider drug safety - there's always the potential that one person somewhere in the world will have an adverse reaction. And because of this core reality, no innovation is possible without some acceptance of uncertainty. But what has happened in some situations has been the pressure to take an extreme interpretation of the precautionary principle and reverse the concepts of science and proof; that is to say unless you can prove safety, you can't do anything at all. This, if you think about it, is an illogical concept and the

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[5] My recent essay expands on these perceptional biases (http://www.pmcsa.org.nz/wp-content/uploads/PMCSA-Risk-paper-2-Nov-2016-.pdf).

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precautionary principle was never meant in those terms. But some lobbyists for a particular position can push to that extreme.

We need to think about how science is related to society and I think all of us understand that whereas science used to stand somewhat aside from society, over the last 30 years, it has become increasingly embedded within society. Not the least this is because we've kept on telling society for the last 30 years that science will help with economic growth, social development and environmental protection. And as governments have invested more and more in science, they and society as a whole expect more engagement in what science is being done and how it is applied. And that's a good thing.

At the same time the pace of innovation has taken off rapidly and this creates both opportunities and challenges for society. Society quite rightly takes time to assess and think about any innovation. But with this there is a growing expectation for societal engagement and scientific co-design. There is also a growing demand for extended peer-review of science and technology. Given this, issues of social licence and science -based technological innovation must also grow.

Why are there these changing relationships? In part it is because science has changed dramatically over the last 60 years. The result of computational development on one hand (including the emergence now of big data) and the molecular sciences on the other have changed what science is possible. An increasing amount of science, even if it is a reductionist experiment, is now framed within systems thinking which moves us from certainty to probabilistic approaches. We're also moving from what's been called normal to post-normal science, where the science is complex and where there is a high values component that is often in dispute. This is particularly so in the environmental, social and health sciences. It is complicated further by the increasing amount of basic scientific innovation arising from industry rather than in public institutions. And of course the life sciences enterprise is growing rapidly and has increasingly embedded links to innovation as every government expects the science community to be better connected to the commercial community.

The post-normal nature of the life science technologies is deeply ingrained and it is thus not surprising that much debate surrounds them. A classic example was the debate (largely non-scientific but masquerading as science) over the safety of the measles vaccine, where controversy was exaggerated by the Wakefield affair, which used manipulated data to the cost to society and many children. There have been debates over-assisted reproductive technologies, and whether they are ethical. Similarly there have been debates over folic acid supplementation of flour and the fluoridation of water. There's also on-going debate in the United States about embryonic stem cells. The genetic modification of plants and animals is an on-going issue across most societies.

Many countries are entering a phase of discussion over non-therapeutic gene-editing, be it for crops or pest control, or for environmental management. There will be also undoubted needs to discuss the implications of a separate but related technology, meiotic gene drive, which would rapidly spread a potentially lethal mutation through an insect colony to eliminate pests.

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Similarly, I think that we've underestimated what the societal reactions to synthetic biology will be, when these techniques come to be applied in the real world.

I am not a futurist but I suspect that when and if new technologies engage directly with the human brain through the introduction of brain performance enhancing drugs (nootropics) or through electronic implants, the debates will be complex and diverse. The latter may involve direct links between individual people and the internet of things via implanted devices that rely on artificial intelligence and machine learning. The ethical issues that might then emerge over loss of autonomy and privacy could be very large indeed.

But, how do we constructively engage in and discuss such issues? For at least the last 10,000 years we have all by definition lived in 'experimental societies'. Humans evolved with manual, cognitive and verbal skills leading to cultural evolution and learning that makes progressive innovation inevitable. Innovation in this context is both sociological and technological. Our societies and concomitant technological innovation have always co-evolved with iterative interactions between them. Consider the development of dairy farming about ten thousand years ago. Dairying changed the societies in which it developed, and dairy diets changed the biology of the individuals within society, allowing the mutation for persistent lactase to be selected for. The interaction continues – we continue to progress new techniques in dairy husbandry and in turn these changed technologies impact on the way our rural societies and economies operate.

Innovation can be seen as a pseudo-Darwinian process, with both selection and niche construction operating: that is some innovations are selected by society to be used, and the innovations themselves change society making it more likely that some of these innovations will be selected. Yet others are disused and become extinct (for example the Walkman) or are displaced by other technological species (streaming of music). By definition, whenever something is introduced into society as an innovation, sociological or technological, there will be some uncertainty as to its adoption and impact, cost and benefit. And all innovations become modified over time, either because of this co-evolutionary process, or because of the result of externalities.

1,000 years ago, the pace and diffusion of innovation was relatively slow, society adapted to it and the impact of society on the innovation was again very slow. Now we have very rapid and diffusible innovation that can have direct and large effects on society. But conversely modern societies have much more diffuse power structures: within populations, there are multiple empowered communities with multiple viewpoints resulting in multiple but uneven influences in turn on technological development.

So what drives the acceptance of some technologies and the rejection of others? First trust in the actors is really important. Of course the technology has to be useful. Secondly, the response of the pre-existing technologies and the Darwinian competition has to play out. Thirdly, it takes time. It took 100 years for margarine to be accepted. And technologies do not evolve in isolation – there is an iterative process of the process of both society and technological adaptation that has to occur. A progressive understanding of costs and benefits will evolve as the technology diffuses. With experience, the empirical understandings of risk

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become clearer. The feared effects of GM foods on health have been shown to be non-existent, and GM ingredients and foods are now widespread. This however does not automatically mean social licence in every context, for there can be many other societal objections than simply safety.

So given this audience, let's think a little bit about genetic modification. The technology was accepted very rapidly into human medicine; we use GM insulin, GM growth hormone and a variety of GM vaccines and yet there's not been societal concern about using GM technologies within medicine. The potential benefits of these products are obvious to most citizens. But there has been a wide range of concerns raised in many societies to using GM approaches in food, agriculture and environmental management.

So why the opposition? Many people have just put it down simply to two factors; a fundamental worldview, that this is scientists 'playing god'; and/or antagonism to a major company dominating in the technology as originally occurred in the seed sector. But as Callestous Juma points out in his book, there have been other deeper factors in play. There were economic factors affecting companies on either side of the Atlantic driving huge differences in the attitudes of the Americans and the Europeans. This is because the Americans were heavily into the technology while the Europeans, with their big chemical companies had fallen behind. With this there has been a lot of pressure put on the European governments to protect their interests. There were European concerns (e.g. the wine growers) over the sociological impact of commercial scale farming. There have been valid fears of the unknown. But these could be and were exaggerated by some often for marketing or political advantage. There has been claim and counter-claim from both sides of the debate. There has been much confused information, hype and exaggerated claims of both risk and benefit and heavily laden language used (eg 'Frankenstein foods') arguably inhibiting constructive societal discussion.

And in response there was sadly a strong Mertonian attitude from many in the science community. So what do I mean by this? In 1942, Robert Merton, the sociologist of science, described scientists as standing apart from society and informing it. That is they had a very patronising view, behaving like priests at the high altar, revealing 'truth' and proclaiming that they knew what's best for society, telling society what to do. Now, hopefully that attitude has largely disappeared, except that we all know scientists who still behave as Merton described in a world where people have access to information and are thus more empowered. Today it is obvious that all citizens must be engaged in dialogue and indeed, they must be part of the process of what science is done, how it is done and how it is used.

The scientific community faces new and important conversations; does gene editing (GE) have a role beyond human medicine? Is GE distinct from genetic modification? How could it be used? Can we separate the reality from the hype? Are there biological, ecological or health risks of significance or not? The issues will get larger as biotechnology beyond GE – for example to apply meiotic gene drive techniques perhaps to eradicate mosquito-borne diseases, to eradicate other pests or to use synthetic biology to mitigate greenhouse gas emissions resulting from agriculture (for example by altering the bacteria in the rumen). Biotechnologists need to engage better and earlier with Society.

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Clearly society has the right and the responsibility to decide on the use of any technology – partly they do this through the market place and partly through political regulation. But regulatory approaches are complex particularly when technologies move fast. The story of margarine amply illustrates this. The regulation of margarine as a whole limited access to a desirable product but the regulation of the type of margarine (for example the elimination of trans-fats) was appropriate. As a result there is an increasing move in some jurisdictions to recognise the problem of regulation based on a technology *per se* as opposed to regulation of specific products of technologies.

Social licence for technology platforms cannot be achieved by deliberative and unitary process in part because with experience and greater knowledge perceptions change. Social licence involves early and continuous engagement of the science community with society at all levels and in all areas. It understands and requires a deep understanding of underlying impacts and concerns. I believe appropriate social licence is much more likely, if we engage better in the concept of co-design, co-production and extended peer-review within science. That is involving people beyond the white-coated scientists in our processes from the earliest stages. I think this ultimately means our young scientists need to be better prepared at university by training in the civic areas of science such as the philosophy of science, and science engagement. The need for social licence requires better acknowledgement of uncertainty, and a better skill set in explaining risks and benefits. We need to be adaptive and most of all, we need to not be as Robert Merton described us in 1942. We have to work out how to be more transparent and engage the community as a whole from the earliest stages, and to do so in ways that sustain and maintain trust.

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