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AUSTRALIAN SCIENCE: WITHOUT IT WE'D BE IN TROUBLE

**************** CHECK AGAINST DELIVERY ****************

Science is everywhere.

It is all around us in our natural world and in our constructed world; and we use it every day as we microwave our porridge, start our cars or get on our bicycles [especially when we (that is, you!) wear lycra] and ride away on our synthetic rubber tyres, or as we use our telephones, or computers, or eat, or take our medicines that we have bought using plastic - banknotes or cards.

It is so much part of our lives that many of us take it for granted: as in: *it will be there when we need it, because it has been in the past.* Perhaps illustrative of this is the fact that just 39% of Australians surveyed recently thought that the benefits of science outweighed the risks. On the other hand, 81% thought they should take an interest because it was such a big part of their lives. [1]

But science is not something that can be turned on or off according to whim or the exigency of the moment. Much of what we use and what we ingest is the result of long-run science. Evidence built upon evidence upon evidence that leads to conclusions that lead to applications.

It is not a new idea to suggest that we get knowledge, and then use it.

Indeed as I heard the other night from Sir Paul Nurse (President of the Royal Society) that Robert Hooke one of the founders of the Royal Society (in the 1660s) emphasised that *scientific discoveries on motion, light, gravity, magnetism and*

[1] DIISRTE (2013) Community attitudes towards emerging technology issues - Biotechnology

the heavens would improve shipping, watches, optics and engines for trade and carriage.[2]

Science, and its application, has surely been with us for a very long time as both an objective and an outcome – way before Hooke.

Indeed, it can be argued that it may have been an important part of human evolution, helping our species to adapt to all sorts of evolutionary pressures and survive while others became extinct - even when they overlapped and sometimes maybe even interbred with our early ancestors.

I note that recent work suggests that about 2% of the genetic material of people descended from Europeans, Asians and other non-Africans is Neanderthal.[3]

So as my eyes wander the room, don't get anxious; I promise to be careful about where I pause.

But how did *homo sapiens* survive at that time while others did not?

It is argued that one of the things that differentiated us from other species was the development of the 'creative' brain. During and post encephalisation there was a lot of brain capacity that could be used to find solutions to increasingly complex problems, and that could have led to an ability to adapt that was either faster or better than the others.

It is a reasonable bet that the creativity that we talk about was more than handprints and drawings on cave walls - as stunning and evocative as they might be; it was also about social groups or tribes working together, and about hunting and harvesting

[2] Paul Nurse, Making Science Work, Canberra, March 2014

[3] Ewen Callaway, *Modern human genomes reveal our inner Neanderthal*, Nature News, 29 January 2014.

and storing all the while adjusting to conditions as they changed.

It is also a reasonable bet that the **creative** brain was a **curious** brain looking for better or more advantageous ways to do things. And when they were found, the species adapted and survived.

Our early ancestors may not have had a grunt that meant 'study mathematics my son or daughter' but they must have used some of the principles of science as they successfully moved out across Europe and Africa.

Indeed, the first known technological innovations (the applications of scientific principles) began to appear in the Middle Stone Age in Africa; our ancestors were using heat-treated mixed compound gluing to make tools and weapons some 72,000 years ago.[4]

The new tools, and the use of tools to make tools, facilitated the transition to a different way of life, and so to survival.

Technological progress continues to be critical to our development – economically, and to our survival. It has been proposed as the factor of production that explains most of the half of historical economic growth that is left after the contribution of known factors (such as land, labour) is accounted for. *As a factor of production, technology produces wealth and produces more technological progress, enabling a virtuous cycle of exponential growth.*[5]

The so-called 'fuel' for technological growth is ideas - new knowledge. Without it, we will never make the leaps that we

[4] Backwell, L et al (2008) J. Archeological Science 35, 1566-1580
[5] WH Press: Science 342, 817, November 2013

need to make; our leaps will be shuffles – small, incremental and not often detectable in a reasonable timeframe.

It is important to note along the way that if we don't replenish the stock of intellectual capital all we do is deplete it. And when that happens, our culture is diminished along with our capacity to adapt, or mitigate or solve the challenges that lie ahead.

And we know from the fossil record what that can mean.

So today is a story about science. It is science in a broad sense and will include technology, engineering and mathematics. It is a story in three unequal parts: science and how it works; why we need science; and how better to get the messages about science out to the community.

Science works because it relies on integrity, evidence and transparency. Jane Lubchenko then head of NOAA said: *Scientific integrity is at the core of producing and using good science. By being open and honest about our science, we build understanding and trust.*[6]

And it is kept honest by its openness. For example, the entire expert peer community scrutinises the output of scientists and it doesn't hold back if the experiments are poorly designed, the hypothesis trivial, the data poor or misinterpreted or even worse, misrepresented.

But, as Paul Nurse said*: experiments and observations alone are not enough. ...Scientists have to come up with ideas that can be tested. ...This distinguishes it from beliefs based on religion or ideology, which place much more emphasis on faith, tradition and opinion.*

[6] Jane Lubchenko, National Oceanic and Atmospheric Administration, United States Department of Commerce.

And when the ideas are tested, and when the data are replicated from different places, with different people and sometimes different disciplines and techniques, we are entitled to conclude that the evidence has stood up to scrutiny and that the evidence is robust.

We then advance with confidence – we know more. And when, after all that, there is a convergence of evidence towards a particular point, we are entitled to say that there is a consensus amongst scientific experts that, say, a particular vaccine is effective and safe.

Opinion or belief has no place in real science; if scientists cannot defend their idea (and their evidence) to their peer community, if they cannot produce the evidence, it doesn't matter how strongly they hold their opinion, it is worth little.

When opinion overrides evidence, it is a sad time for humankind. And it is a truly frightening time for humankind when scientists (and their science) are derided even vilified because their evidence (after close and expert scrutiny) happens not to fit with what some people want to hear.

Building a body of evidence takes time. But sometimes the issue at hand has implications that are so profound, action has to be taken. Taking action based on the available evidence when it is strong, even if still a work in progress, is better than making policy with no evidence base at all, or possibly worse, simply delaying a decision in the hope that perfect data will offer absolute certainty sometime soon. It doesn't work that way.

Of course the public might want answers and find it confusing when scientists are not in complete agreement, or when the evidence is evolving rapidly. It is often difficult to explain that this is science at it strongest, not at its most fractured or weakest. The contest of ideas, the replication, the intense scrutiny are simply what we do.

It is a good way. It is an important way because it leads to good science and we need good science, now.

The facts are fairly clear: most of the challenges that confront us as a people will have science and the application of scientific principles somewhere close to their core if we are to adapt, mitigate or even solve some of those matters.

We need therefore to support science in order for it to support us. We need the knowledge that it will generate and we need to be able to use it. Without it, where would we be?

It is, then, important to support the full spectrum of research, from discovery through translation to use. Quoting Paul Nurse again, *we need to recognize that there is a continuum from discovery science acquiring new knowledge, through research aimed at translating scientific knowledge for application, onto subsequent innovation. This spectrum should be considered as an interactive system, with knowledge generated at different places within the continuum….*

Or as Derek Bok[7] put it when writing about the role of America's universities:..*the division between pure and instrumental inquiry is much too sharp. It is possible to explore a subject out of a keen desire to understand it better* ***and*** *a belief that such an understanding may be of use to humankind…* He sounds like a contemporary Hooke!

[7] Derek Bok, *Universities and the future of America*, Duke University Press, 1990.

It would be unwise, to be generous, to believe that all we need is a bunch of people sitting around wondering how to make a better cog. Although some should.

Derek Bok also wrote that American universities *have ceased to be small, cloistered institutions serving a tiny elite..* focussed exclusively on their *..capacity to do original work of pure research and scholarship... But it would be silly and precious to insist that work of this kind is the only proper pursuit for all or even a large fraction of our huge professoriate.*[8]

It would be **as** unwise, and **still** generous, to believe that all we need for our future to be secure is a bunch of researchers sitting around deep in scholarly thought communicating with each other but with little to no interest in the issues that confront the communities that support them. But some should.

It is about balance. And we have to find the right balance.

The balance was not lost on Norm Augustine, former President and CEO of Lockheed Martin, who went to the US Congress to seek increased investment in education and research.

One member, obviously frustrated, asked: *Mr. Augustine, do you not understand that we have a budget crisis in this country?*

He responded: *I am an aeronautical engineer and during my career I have worked on a number of airplanes that during their development programs were too heavy to fly. Never once did we solve the problem by removing an engine. Education and the creation of knowledge are the engines that drive our economy, jobs and standard of living. Only by working together*

[8] Derek Bok, *Universities and the future of America*, Duke University Press, 1990.

can government, industry and academia meet the great challenge we confront.

Paul Nurse put it differently: *cutting funding for science during an economic downturn is like burning the seed-corn, it will only damage our economic recovery and future sustainable growth.*

In Australia, we are not good at the working together bit. The OECD looked at the level of business collaboration with higher education or public research agencies.[9] Australia was 33rd of 33 countries, well behind the 32nd - Mexico; just around 4% of our large firms collaborated and very slightly more of the SMEs. This compares with Sweden (5th) where it is about 50% and 10% of the SMEs or the UK (19th) where it is about 30% and 20%.

Now I know that when I raise matters like this one of two things normally happens: one is that I am told the data are wrong, and we go back to sleep; the other is that we find some other way to re-present the data to our advantage, and go back to sleep. And I do know about different economies and profiles, too. But surely there is a message in there that we have to consider.

Look at the UK. There, just over 30% of their researchers are in business and 65% in universities; in Australia, just under 30% are in business and about 60% in universities.[10] So our researcher profiles in terms of location (and culture) are similar and yet there is much more collaboration in the UK. Why? The fact that they have real strategies and incentives that endure might be part of the explanation. We do not have such strategies. And we should.

[9] OECD Science, Technology and Industry Scorecard 2013 - based on Eurostat (CIS-2010) and national data sources, June 2013.

[10] UNESCO Institute of Statistics

The reality for us in Australia is that we can't do everything. It might be nice to think that we could – but we can't. Therefore it does mean making choices and being smarter. It doesn't mean picking winners in the old way of thinking, but it may well mean that politicians **acting on expert advice** could identify a budget, key priorities such as particular areas where Australia must be engaged, or key infrastructure within a priority framework. They should then leave the decisions on which of the projects to fund to researchers and the peer community.

These issues are important when we look at developing our scientific and innovative capability. We have a choice.

We can continue to muddle along, dabble at the margins and let what is represented to us as a market, decide. Or we can get real. We can be strategic with a proportion of our investment and be better at ensuring that national needs and competitive advantage are important parts of the agenda.

If this were so hard in a free-market democracy, why is it that the United States, the United Kingdom, and many of the European Union countries have decided that a strategy for science is needed?

And it isn't even the latest flash of the light bulb. In 1998, the US House of Representatives Committee on Science released a document entitled "Unlocking Our Future: Toward a National Science Policy".

It said*: No entity as vast, interconnected and diverse as the science and engineering enterprise can successfully operate on autopilot perpetually.*

What are the messages for us?

I think when it is all put together it tells us that we should have a comprehensive strategy, too – connecting and embracing the key pillars: education, research, innovation, international linkages and community engagement.

But we lack the urgency found elsewhere – even the urgency seen in countries that already out-perform us - and we risk being left behind.

Our approach is different. While we are unhappy about the rate of research grant success, or the level of funding, we don't do much about it – other than asking for 3% of GDP because others have that target, and because we could spend it.

I suggest such an approach is counterproductive, hardly ever successful and the antithesis of strategic – roughly akin to the overuse of terminating program grants.

If we were to set out what we were willing to do in return for additional funding we might get traction, especially if it is off the back of a thorough investigation into what we need to do, and what we can realistically do compared with what we presently do, and an assessment of where we have real competitive advantage and national needs that should be met.

Being strategic about science is an obvious choice for us, and overdue.

How can we expect to build future prosperity and national wellbeing with a 'she'll be right' attitude?

In the US, it is suggested that 60 per cent of the workforce in 2020 will require skills held by only 20 per cent of the current workforce.[11] In the United Kingdom, industry will need 830,000

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[11] American Society for Training & Development, *Bridging the Skills Gap*, pg 10, 2009.

new science, engineering and technology professionals and 450,000 technicians between now and 2020.[12]

So they do something about it.

By contrast we continue to accept that the study choices of students in year 10 can influence the skills available to our workforce four to six years later.

We can't compel but we can encourage.

I suggest that we might need a strategic, probably incentive-based, approach to ensure that we get a balance in study choices that might bear some relationship to future workforce needs. Or research and development needs.

Instead we are told about a market, and its 'pull factors' and what we can't do, rather than finding a way to do what we must do.

So we turn to the international labour market to meet the needs of the scientific and technical job markets.

In the ICT sector, Australian companies sponsored ~36,000 457-visas between 2006 and 2012.[13] During the same period, we graduated ~15,600 domestic students in IT; BUT our output more than halved in the decade between 2003 to 2012.[14]

Similarly, Australian businesses sponsored about 12,000 457-visas in professional, scientific and technical jobs between 2008 and 2012.[15] We produced 60,604 science graduates during this period; our graduate output did increase from 2010

[12] Royal Academy of Engineering, econometrics of engineering skills project, *Jobs and growth: the importance of engineering skills to the UK economy*, pg 23, 2012.
[13] Department of Immigration & Citizenship, Subclass 457 Statistics
[14] Department of Education, Higher Education Statistics, custom dataset
[15] Department of Immigration & Citizenship, Subclass 457 Statistics

as did our enrolments, and employment increased by about 14% over the five years to 2011, against 9% for other jobs.[16]

But this is not a market with just one player – us. There is growing competition for talent and skills around the world. And there will be a high cost to pay if we fail.

A bit of independence might be in order – how about the notion of 'talent and skill security', to go along with all the other securities that we talk about, like energy security and food security and water security to name a few. I note in passing that none of the latter would ever be realisable without science.

And it even makes economic sense.

In 2013, the European Physical Society commissioned an independent economic analysis covering 29 European countries.

It showed that over the four-year period 2007-2010 the physics-based industrial sector generated around 15% of total turnover in Europe's business economy. That exceeds the contribution made by the entire retail sector.

The same study found that the sector supported more than 15 million jobs corresponding to more than 13% of overall employment in the business economy of Europe.

Chemistry started saving lives when synthetic pharmaceuticals were developed.[17] It spawned an industry...

[16] ABS Media Release, Qualifications paying off in science, technology, engineering and maths. 24 February 2014

[17] Holmes, A., *Proteins to plastics: chemistry as a dynamic discipline*, The Conversation, 25 February 2014. http://www.chiefscientist.gov.au/2014/02/australia-2025-smart-science-chemistry-2/

Mathematics makes a complex world more comprehensible and manageable, intertwined as it is with efficiency and innovation at all levels of the economy, and security.[18]

Computational mathematics plays a lead role in industrial, biological, economic and environmental modelling, such as in the increasing accuracy and sophistication of climate change models.

Bioinformatics plays a lead role in genetics, creating algorithms to analyse genomic data to identify genetic markers for disease.

It is all important, and integrated into our ways of life.

But as Carl Sagan once famously said: *we live in a society exquisitely dependent on science and technology, in which hardly anyone knows anything about science.*[19]

And it is our job to change that; not just to know it but also to do something about it. No matter how much we talk to each other and persuade each other that it is all important, we have to get the message out. We have to inform the public and keep them engaged.

The community must have confidence that the approaches taken by scientists and the quality of their work meet their needs, aspirations and ethical expectations.

And they must be in a position to make judgments. They will have to be alert and understand the differences between scientific evidence and, say, the commentary from vested interest groups in our community who can surely find

[18] Prince, G., *Optimising the future with mathematics,* The Conversation, 11 March 2014. http://www.chiefscientist.gov.au/2014/03/australia-2025-smart-science-mathematics/
[19] Sagan, C., The Skeptical Inquirer, *Why we need to understand science*, Vol 14, Issue 3, 1990.

somebody somewhere to give them a line that they can use to sow doubt.

Widespread understanding of the scientific process is important in a community. People often encounter claims that something is scientifically known; or these days, a denial of strong scientific evidence. If they understood how science generates and assesses evidence bearing on these claims, they can make a better informed decision when they are asked to make one. I suppose this is back to our education system – and a plan and a strategy.

Given the importance of matters that we know lie ahead – let alone speculating about what we don't know -– we need an informed discussion where scientific evidence is properly evaluated and seriously discussed and in which the views of the outliers, the lobbyists and the hobbyists are given due consideration but not undue weight.

And we need to provide the knowledge that will enable us to cope when the unpredicted becomes the burning issue of the moment.

Science will provide the evidence, the knowledge and the skills. The community and its political leaders will determine the response. Our job, your job, is to provide the best possible evidence that you can as you engage in the disinterested search for knowledge and its translation into goods and services that will improve the lot of human-kind. And to explain it carefully and clearly.

And if we are to prosper, *If Australia is to be successful in transforming to a new economy that can meet the challenges of the 21st century, then research and innovation needs to be at* *the very heart of Australia's economic, industry, social, national security and foreign policy.*[20]

Let me end near where I started. If we are to survive and hand on a planet that is worth handing over to those who will follow, we will need science and we will need scientists.

It will be curiosity, ideas, knowledge and the application of scientific principles and knowledge that will play a big part in preventing us from going the way of the Neanderthals.

[20] Department of Industry, Innovation, Science, Research and Tertiary Education (2012), *2012 National Research Investment Plan*, p12.