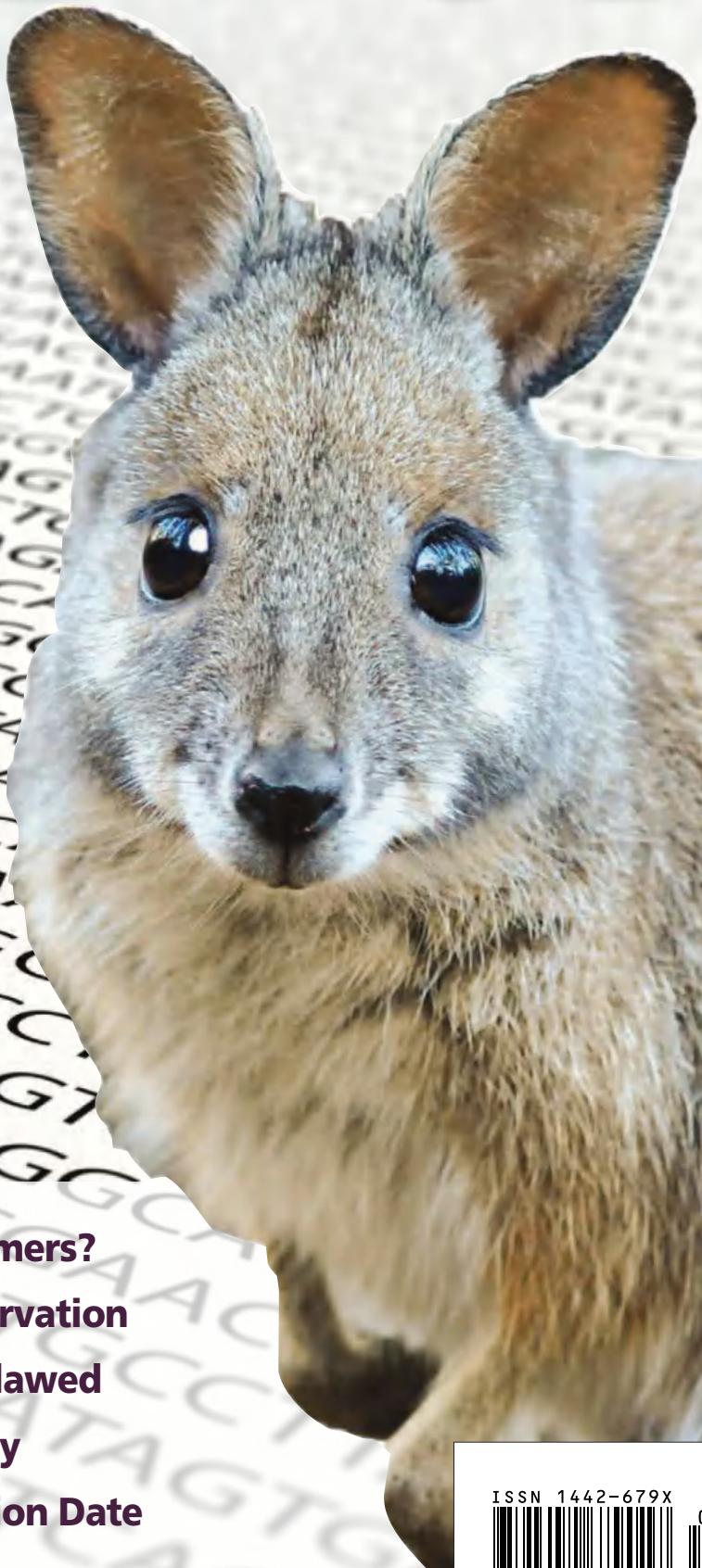


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Decoding Australia's Mammal Genomes

The species whose genomes will reveal the evolutionary history of Australia's mammals and aid their conservation



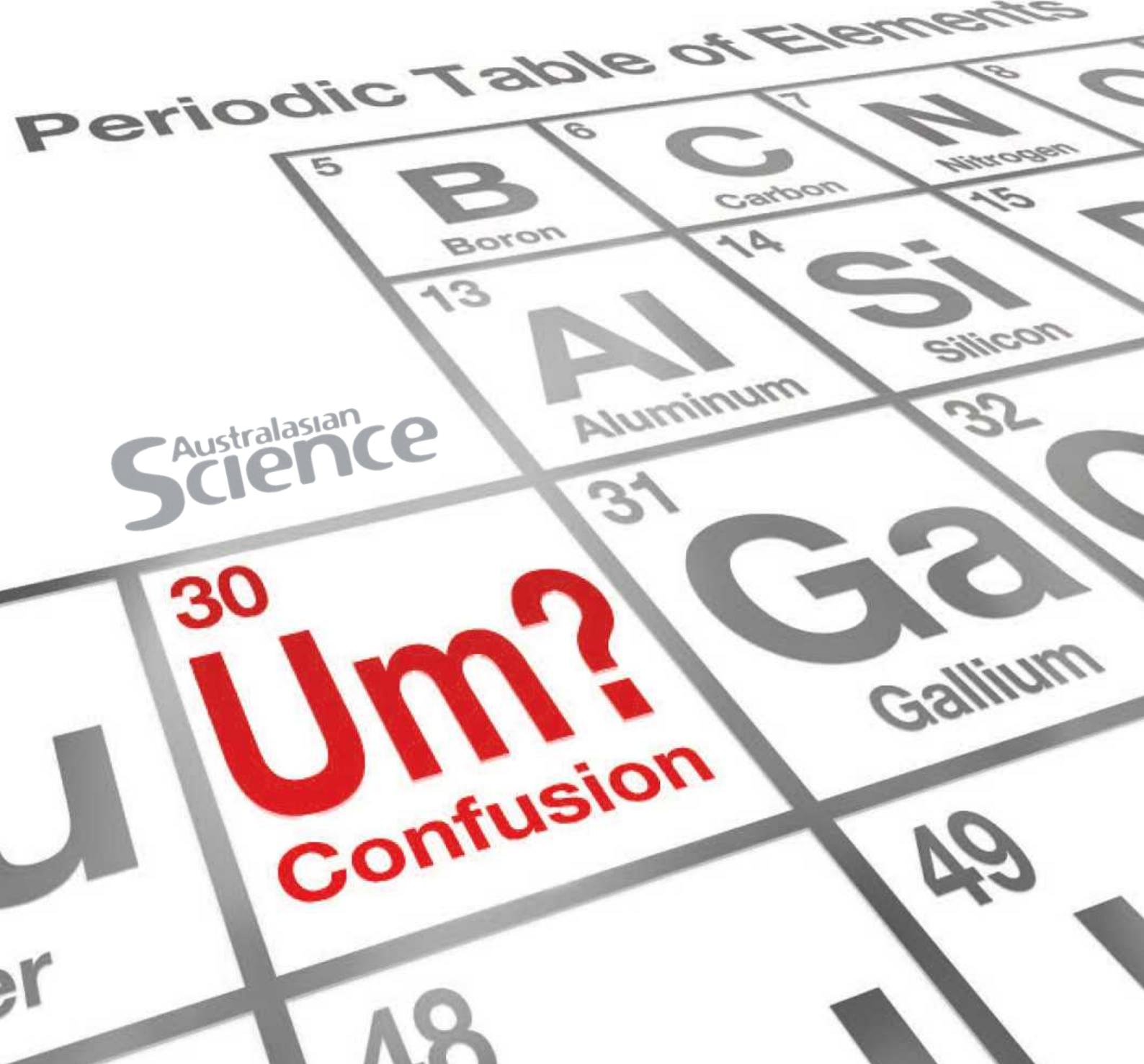
Were Termites the World's First Farmers?

Commercialising Wildlife for Conservation

Why the Sports Doping System Is Flawed

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Ancient Gecko Reveals Desertification Date



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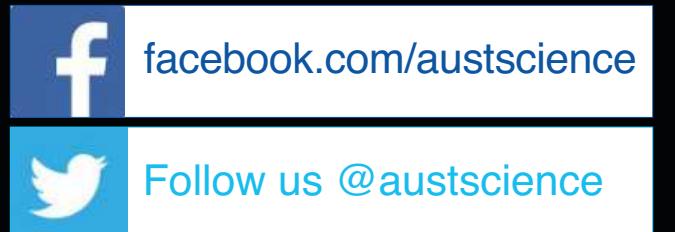
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"We Have Always Been at War with Science"

An Orwellian dystopia is upon us when scientists are muzzled and their expertise disappears into a memory hole.

When I was a student I was fascinated by the dystopian future imagined by George Orwell in *1984*. The thought of an extensive network of cameras, microphones and two-way telescreens to monitor each citizen seemed far-fetched in the 1980s, let alone the concept of government departments dedicated to rewriting historical records, but in 2017 we now seem to have caught up with Orwell's imagination.

Our computers all have video cameras that can be hijacked by hackers; our ATM and credit cards record every purchase we make; GPS tracking of our mobile phones records our every movement; the cameras on millions of phones enable a mobile army of citizens to record and broadcast on social media what were once considered unremarkable events; and governments can track our phone calls, emails and browsing history. This volume of information can quickly generate a detailed profile of us all.

Much of this has been evolving since the start of the millennium. Where 2017 is now echoing *1984* is in the emulation of a Ministry of Truth by new US President Donald Trump. While Trump's election campaign last year was the flagbearer for the "post-truth" era, his inauguration has seen this morph into the blatant creation of "alternative facts".

But Trump is not waging a war against Eurasia or Eastasia. He's waging a war against science. When your philosophy is to create a Ministry of Truth that churns out alternative facts, the knowledge collated by science over the course of centuries becomes an irritant. Hence it's not surprising that in its first week the Trump Administration took to muzzling scientists and wiping any mention of science that conflicted with Trump's agenda.

While in *1984* Winston Smith discarded previous versions of the public record into a "memory hole", the Trump Administration immediately began removing references to climate change policy on the White House's website. After all, the science of climate change is an inconvenient truth for a President who wants to reduce "burdensome regulations on our energy industry".

In almost the same sweep of his tiny hands, Trump attempted to put a muzzle on government scientists, requiring political appointees to review and approve all public communication by several agencies including the Environmental Protection Agency. The gag encompassed everything from scientific data to press releases, blogs and tweets.

But anything can happen in America. Not here, right?

Wrong. It's not so long ago that CSIRO's climate scientists were gagged, and there are already signs that events like Trump's election and Britain's decision to leave Europe will see post-truth politics adopted in several other countries, including Australia.

Australia's Chief Scientist, Alan Finkel, has likened Trump to Josef Stalin, who famously placed the Soviet Union's agriculture in the misguided hands of Trofim Lysenko. "While Western scientists embraced evolution and genetics, Russian scientists who thought the same were sent to the gulag," Finkel said. "Western crops flourished. Russian crops failed."

One of Big Brother's slogans was: "Ignorance is strength". But that's only true in a dystopian society.

Guy Nolch is the Editor and Publisher of *Australasian Science*.



Cover Story

A large project to sequence the genomes of Australia's mammals will provide the first complete picture of their interrelationships and evolutionary history – and aid their conservation (see p.19).

Credits: Australian Wildlife Conservancy, Mopic/Adobe

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Stress Hormones Underlie Indigenous Health Gap

James Cook University scientists have found that secretion of the stress hormone cortisol is impaired in young Indigenous adults, and that their biological stress response is linked to the racial discrimination they experience.

The study, published in *Scientific Reports*, showed for the first time that the morning increase of cortisol that prepares us to effectively deal with the stresses of the upcoming day is missing in otherwise healthy young Indigenous adults.

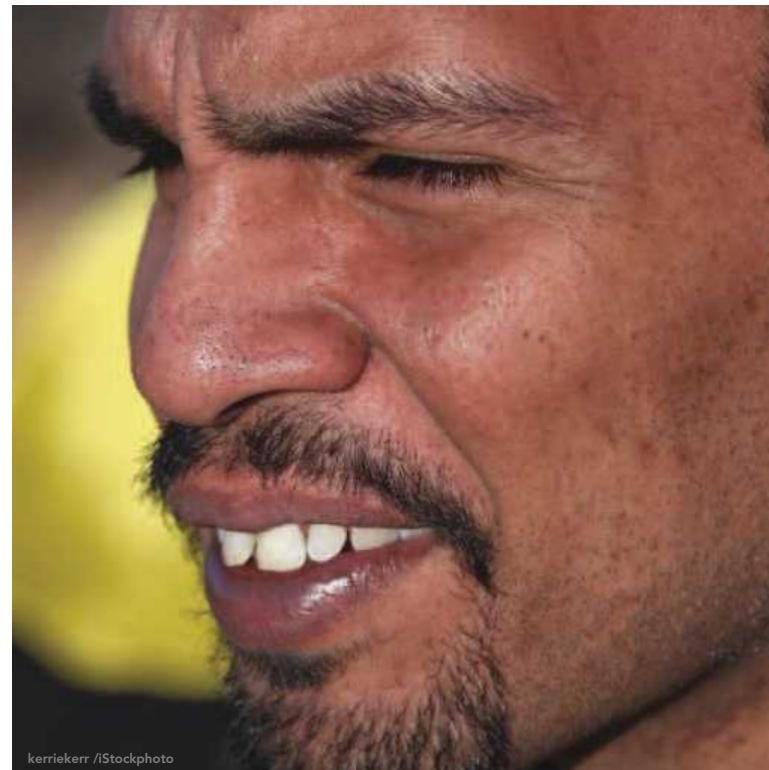
Prof Zoltan Sarnyai of JCU's Australian Institute of Tropical Health and Medicine explained that cortisol concentration in the blood should be within a certain range. "Too little or too much of it is dangerous for health," he said. "We can't tell why it is low in this case."

"One possible explanation is that previous stress, early traumatic events or even traumas of the past generation may have impaired the negative feedback system, so the brain and the body feel as if there is too much cortisol around. So it shuts off its own cortisol production after awakening."

The absence of the morning cortisol rise was related to the levels of chronic stress the participants had experienced. Patients with common and severe mental disorders, including depression and psychotic disorders, are similarly missing such a morning rise.

The study's first author, Dr Maximus Berger, said there is evidence that the missing morning rise of cortisol indicates a risk of poor mental health in the future. This raises the possibility of using this measure to study the risk of future mental health problems in young Indigenous Australians and other First Nations people worldwide.

Berger and his colleagues found that the hormonal stress response was blunted in Indigenous participants who reported high levels of internalised racism (the acceptance of ethnic stereotypes relating to members of one's own group), which points towards a link between discrimination and an inadequate response to stress.



kerriekerr /iStockphoto

Sarnyai said it is highly unlikely that the observed abnormalities are due to genetic factors, since the non-Indigenous control group was comprised of an ethnically diverse group of individuals.

However, this study cannot rule out that epigenetic changes – the process by which a gene is switched on or off without changing the DNA code – caused by early experiences and even by transgenerational traumas might play a role.

Sarnyai said the study could open up a new avenue to predict the development of mental health problems in First Nations people. "It may allow us in the future to objectively monitor efficacy of programs and policies to reduce the Indigenous health gap," he said.

Immune Response Triggers Side-Effects to Common Drugs

Australian researchers are a step closer to understanding immune sensitivities that cause side-effects from commonly prescribed medications.

Their study, published in *Nature Immunology*, investigated which drugs might activate a specialised type of T cell that detects infection. They found that some drugs prevented these MAIT cells from detecting infections while other drugs activated the immune system, which may be undesirable.

Dr Andrew Keller of Monash University's Biomedicine Discovery Institute said that T cells are an integral part of the body's immune system. "They protect the body by 'checking' other cells for signs of infection and activating the immune system when they detect an invader," he said. "This arrangement is dependent on both the T cells knowing what they're looking for, and the other cells in the body giving them useful information."

PhD student Weijun Xu of The University of Queensland's Institute for Molecular Bioscience used computer modelling to predict chemical structures, drugs and drug-like molecules that might impact on MAIT cell function. Such small compounds included salicylates, non-steroidal anti-inflammatory drugs like diclofenac, and drug metabolites.

Dr Sidonia Eckle of the Peter Doherty Institute for Infection and Immunity at The University of Melbourne said the implications point to possible links between known drug hypersensitivities and MAIT cells. "A greater understanding of the interaction between MAIT cells and other host cells will hopefully allow us to better predict and avoid therapeutics that influence and cause harm," she said. "It also offers the tantalising prospect of future therapies that manipulate MAIT cell behaviour, for example, by enhancing or suppressing immune responses to achieve beneficial clinical outcome."

Extreme Fires to Increase

Increasingly dangerous fire weather is forecast for Australia and the Mediterranean as the global footprint of extreme fires expands, according to a report published in *Nature Ecology and Evolution*.

An international collaboration of researchers compiled a global satellite database of the intensity of 23 million landscape fires recorded between 2002 and 2013. Of these, the researchers honed in on 478 of the most extreme wildfire events.

"With the exception of land clearance, the research found that extremely intense fires are associated with anomalous weather – such as droughts, winds, or in desert regions, following particularly wet seasons," said Prof David Bowman of The University of Tasmania.

"Of the top 478 events we identified 144 economically and socially disastrous extreme fire events that were concentrated in regions where humans have built into flammable forested landscapes, such as areas surrounding cities in southern Australia and western North America."

Using climate change model projections to investigate the likely consequences of climate change, the research predicted more extreme fires for Australia's east coast and the Mediterranean region spanning Portugal, Spain, France, Greece and Turkey. "The projections suggest an increase in the days conducive to extreme wildfire events by 20–50% in these disaster-prone landscapes, with sharper increases in the subtropical Southern Hemisphere and the European Mediterranean Basin," Bowman said.



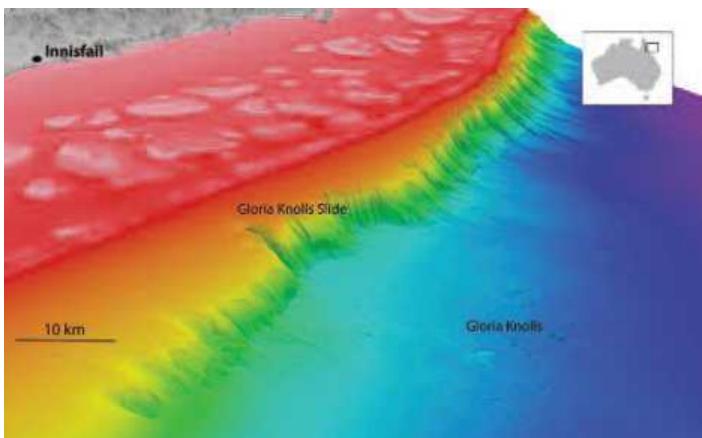
Largest Undersea Landslide Revealed on the Great Barrier Reef

Scientists have discovered the remnants of a massive undersea landslide on the Great Barrier Reef, approximately 30 times the volume of Uluru.

The remains of the slip, known as the Gloria Knolls Slide, were discovered 75 km off the Queensland coast near Innisfail. "This is all that remains after a massive collapse of sediment of about 32 cubic kilometres' volume more than 300,000 years ago," said Dr Robin Beaman of James Cook University.

Beaman said a debris field of large blocks, or knolls, and numerous smaller blocks, lies scattered over 30 km from the main landslide remains, into the Queensland Trough, to a depth of 1350 metres. "We were amazed to discover this cluster of knolls while 3D multibeam mapping the deep GBR seafloor," he said. "In an area of the Queensland Trough that was supposed to be relatively flat were eight knolls appearing like hills, with some over 100 metres high and 3 km long."

A sediment sample from a knoll at a depth of 1170 metres identified a remarkable cold water coral community of both living and fossilised coral species, gorgonian sea whips, bamboo corals, molluscs and stalked barnacles. "The oldest fossil corals recovered off the top of the knoll was 302,000 years, which means the landslide event that caused these knolls must be older," says lead author Dr Angel Puga-Bernabéu of The University of Granada.



A north-westerly view of the Gloria Knolls Slide and Gloria Knolls off the coast of Innisfail. Depths are coloured red (shallow) to blue (deep) over a depth range of about 1700 metres. Credit: www.deepreef.org

Modelling revealed that the landslide could have led to a tsunami wave measuring 27 metres. However, the wave would likely have been damped significantly by the presence of any coral reefs.

The researchers say that considerably more seabed mapping and sampling is needed to fully assess the tsunami hazard to the Queensland coast posed by underwater landslides.

With one-third of the Great Barrier Reef situated beyond the seaward edge of its shallower reefs, the researchers say that the discovery of this prominent undersea landslide and its vast debris field reveals a far more complex landscape in the deep Great Barrier Reef than was previously known.

Fertilisers Make Plants Weaker

As well as causing soil damage and environmental problems from run-off, research published in *Proceedings of the Royal Society of London B* (<http://tinyurl.com/hzjkj58>) has found that nitrogen-based fertilisers also reduce a plant community's resistance to fungal diseases. The researchers warn that prolonged use of artificial fertilisers can lead to the extinction of the most resistant plant species in a community, making the remaining species more susceptible to diseases.

In experimental field trials, researchers from Flinders University in Adelaide and Fudan University in Shanghai tested the biodiversity resilience of an isolated plant community in a native alpine meadow on the Qinghai-Tibetan Plateau. The 20-hectare experimental meadow, which has been spared from yak grazing for the past 20 years, contains a rich and diverse plant community.

"In this diverse and pristine ecosystem, we have established that extended fertilisation of soils not only alters the structure of natural plant communities, it also exacerbates pathogen emergence and transmission," the researchers concluded.

Prof Corey Bradshaw of Flinders University says that this is one of the ways in which crop monocultures succumb to sudden outbreaks of severe disease. "Having more species in an ecosystem provides a sort of insurance policy against disease for any given species because of what's known as the 'dilution effect,'" he said. "This means that when there are a lot of species in any given area, the chance of passing a disease pathogen from an infected individual to a neighbour of the same species is lower, so the entire community benefits from an overall lower prevalence and severity of diseases."

The project's leader, Prof Shurong Zhou of Fudan University, described one of the main mechanisms of this disease-dilution effect: "Adding fertilisers makes certain species outcompete others, leaving the overall biodiversity of a system lower and more susceptible to disease," Zhou said. "In other words, while some species benefit from adding nitrogen, the overall effect at the community level could be worse because the surviving species end up being more diseased."

Bradshaw added: "These experiments provide powerful information about how species diversity maintains ecosystem function, and how agriculture and other human interventions can accelerate ecosystem degradation".



Herbal Medicine's Hidden Risks Pose a Threat to Health

The perception that herbal medicines are safe because they are derived from natural materials and have been in use for thousands of years could see people unknowingly putting their health at risk, according to a report in the *Medical Journal of Australia*.

The report highlights a range of issues relating to the preparation of complementary medicines, warning that some traditional herbal preparations contain toxic chemicals from both animals and plants, as well as heavy metals and pesticides.

"Toxic side-effects of herbal medicines used in traditional societies have typically not been reported, and this is often cited in favour of their safety," says lead author Prof Roger Byard of The University of Adelaide. "However, the lack of systematic observation has meant that even serious adverse reactions, such as the kidney failure and liver damage caused by some plant species, have gone unrecognised until recently."

More than half of people using complementary medicines, including herbal products, do not inform their doctors. "The problem with this is that drug interactions are poorly recognised in herbs," says co-author Dr Ian Musgrave. "Not only can herbal medicines interact with traditional pharmaceutical medicines but also with other herbal medicines the patient may be using."

The authors say that due to relatively light regulation of the industry, the content and quality of herbal preparations are not as tightly controlled as standard pharmaceuticals. "A significant number of traditional herbal medicines do not comply with Australian regulations," Musgrave warns. "In some cases, ingredients are either not listed or their concentrations are recorded inaccurately on websites or labels."

"In other cases a botanical species may be replaced with another if it is difficult to source or too expensive. The replacement species may be potentially toxic. Most worryingly, a few products are illegally adulterated with standard pharmaceuticals to increase the effectiveness of the herbal product," Musgrave says.

Byard adds that "it would be appropriate for the Therapeutic Goods Administration to require manufacturers to have samples independently tested before placing them on the market. Legal action should be considered in cases of non-compliance with applicable regulations, and preparations containing illegal substances should be banned."

Musgrave says that this will require "more testing, more documentation, and this will naturally incur more costs for industry. There will be a reluctance from industry to do this, but while they claim that for thousands of years they have been using herbal products without such tests, the potential risks to human health mean that there is due cause for reasonable, scientifically rigorous testing."

Sitting Absolved from Diabetes Risk

New research published in the *British Journal of Sports Medicine* has ruled out sitting as a direct cause of diabetes.

"Sitting has attracted a lot of publicity in recent years for being as dangerous as smoking and for being harmful regardless of how physically active people are," said lead author A/Prof Emmanuel Stamatakis of The University of Sydney's Charles Perkins Centre. "While these findings don't exonerate sitting, they do suggest that there is far more at play than we previously realised when it comes to sedentary behaviours and the health risks associated with extended sitting."

Stamatakis and colleagues analysed responses from a long-term health study completed by 4811 middle-aged and older London-based office workers who were initially free of diabetes and major cardiovascular disease. In 1998 the participants were asked to report the amount of time they spent on various sitting behaviours, including at work and commuting, leisure time and watching television. They then examined clinical data based on blood glucose levels from the same cohort until the end of 2011 to determine whether new cases of diabetes occurred over the 13-year follow-up period, adjusting for confounding factors such as physical activity, quality of diet, employment grade, alcohol and smoking habits, general health status and baseline body mass index.

In total, 402 cases of incident diabetes occurred during the follow-up period, yet there was little evidence for associations between sitting and diabetes, and these weak associations were limited to TV sitting time.

A Smart Cane for the Blind

Engineers from The University of Melbourne have developed a prototype device for the visually impaired that uses lasers and a camera to identify non-protruding obstacles such as kerbs, potholes, descending stairs and dips in the pavement. The prototype can be attached to a cane, walking frame or wheelchair.

The idea for the device arose after A/Prof Elaine Wong's now 9-year-old child was born with congenital blindness. She contacted Vision Australia and offered her skills as an engineer in the hope she could help improve the independence and safety of the vision-impaired. "I wanted to do something tangible, that could have a real impact. Maintaining people's quality of life cannot be underestimated," she says.

The team's next step is to miniaturise the prototype and refine the lasers so they work under all lighting conditions. They also aim to make the final device as cheap, portable and user-friendly as possible for the 360,000 vision-impaired people in Australia and the 285 million worldwide.

"While the real-time navigation and safety gains are obvious, there are also clear social benefits in helping vision-impaired people continue their social interaction, ensure they stay healthy as they get older, and develop confidence and skills in getting around," Wong says.



YakobchukOlena/Adobe

"Importantly, our research was among the first long-term studies to distinguish between various types of sitting behaviours, not just TV sitting, which is used in the majority of existing studies. But TV time and sitting time are practically uncorrelated so we have very good reasons to believe that the health risks attributed to TV in the past are due to other factors, such as poorer mental health, snacking and exposure to unhealthy food advertising," Stamatakis said.

"Many previous studies also rarely acknowledge how higher BMI at the outset of the study increases the participant's risk of developing diabetes, which could compromise study results.

"Another reason for our results could be that these London-based workers were protected by the large amounts of walking they reported, which was nearly 45 minutes per day on average. With most white-collar workers forced to spend many hours each day in front of a computer not moving, this amount of physical activity may be an absolute necessity to maintain good health."



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A cone snail on the hunt for prey.

Acid Trips Cone Snails

Deadly cone snails are too clumsy to catch their prey when exposed to the levels of ocean acidification expected due to climate change, according to research published in *Biology Letters* (<http://tinyurl.com/hf3npjh>).

The study reveals the impact that rising carbon dioxide levels could have on the ocean food chain. "We found the carbon dioxide made the cone snails hyperactive," says lead author Dr Sue-Ann Watson of the ARC Centre of Excellence for Coral Reef Studies at James Cook University. "But despite moving three times faster than normal they caught fewer prey. They meandered around instead of moving by stealth and sneaking up on their prey."

Cone snails typically hide in the sand to surprise their enemy. They harpoon their prey using a powerful venom that can also be fatal to humans.

The scientists took cone snails from around Lizard Island, on the Great Barrier Reef, and put them into tanks with a popular cone snail delicacy – jumping snails – but only 10% of the cone snails under the influence of elevated CO₂ managed to catch their dinner compared with 60% of those kept in tanks under normal conditions.

Ocean acidification occurs when the ocean absorbs carbon dioxide from the atmosphere, resulting in chemical changes as the pH of the water decreases. "We already know that ocean acidification will weaken snails' shells, and this new research shows it can also affect their energy levels by increasing activity while at the same time decreasing their food intake," said Prof Philip Munday.

Previous work by Watson has shown that the behaviour of the cone snail's prey, such as jumping snails, is altered by elevated CO₂ levels. This new study shows that predator behaviour is affected as well.

"As the behaviour of species change under these conditions, so too can the relationship between predator and prey," Watson said. "The results of this study could have implications for food chains beyond cone snails and their prey."

"Marine snails and other molluscs are important for the ocean food chain, and are also resources for humans. If their behaviour changes there could be a flow-on effect in the food chain. These changes could potentially affect commercially important seafood species," Watson said.

Astronomers Find Evidence of "Missing Link" Black Hole

An international team of astronomers has announced new evidence for the existence of a middleweight black hole in space – the "missing link" between stellar mass and supermassive black holes.

The intermediate-mass black hole, announced in *Nature*, has 2200 times the mass of our Sun and hides at the centre of the 12-billion-year-old globular 47 Tucanae star cluster, 13,000 light-years from Earth in the southern constellation of Tucana the Toucan.

The 47 Tucanae cluster contains three millions stars in a sphere about 120 light-years in diameter. It also holds about two dozen pulsars that were important targets of the investigation.

The new research relied on two lines of evidence. The first is overall motions of stars throughout the cluster.

A/Prof Holger Baumgardt of The University of Queensland, who conducted computer simulations used in the research project, said that a globular cluster's environment was so dense that heavier stars tended to sink to the centre of the cluster. "An intermediate-mass black hole at the cluster's centre acts like a cosmic 'spoon' that stirs the pot, causing the stars near it to slingshot to higher speeds and greater distances, imparting a subtle signal that astronomers can measure," he said.

By employing computer simulations of stellar motions and distances, and comparing them with visible-light observations, the team found evidence for just this sort of gravitational stirring.



Artist's impression of a black hole bending space-time in a crowded field, with pulsars bound to it by gravitational forces.

Baumgardt said the second line of evidence came from pulsars, compact remnants of dead stars whose radio signals were easily detectable. These objects were also flung about due to the gravitational influence of the central intermediate-mass black hole, causing them to be found at greater distances from the cluster's centre than would be expected if no black hole existed.

Combined, this evidence suggested the presence of an intermediate-mass black hole of about 2200 solar masses within 47 Tucanae. The fact this black hole had eluded detection for so long suggests that black holes of similar masses could be hiding in other globular clusters.

Graphene Made from Soybeans

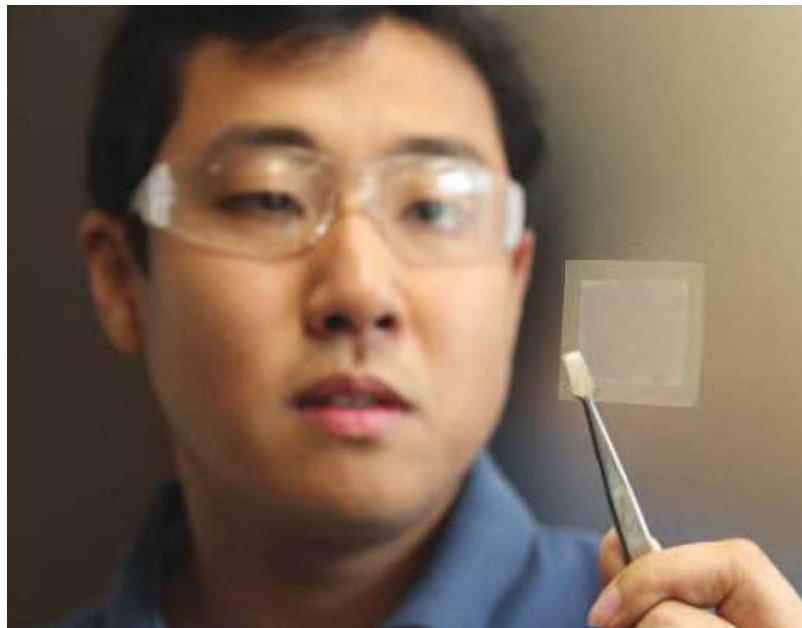
The world's strongest material has been made more commercially viable with the development of new technology that transforms soybean oil.

Graphene is a carbon material that is one atom thick. Its thin composition and high conductivity has led to its use in applications ranging from miniaturised electronics to biomedical devices. These properties also enable thinner wire connections, providing extensive benefits for computers, solar panels, batteries, sensors and other devices. Until now, though, the high cost of graphene production has been the major roadblock in its commercialisation.

Graphene is typically grown in a highly controlled environment containing explosive compressed gases, requiring long hours of operation at high temperatures and extensive vacuum processing. Now, however, CSIRO scientists have developed a novel technology that eliminates the need for such a highly controlled environment.

The "GraphAir" technology grows graphene film in ambient air with a natural precursor, making its production faster and simpler. "This ambient-air process for graphene fabrication is fast, simple, safe, potentially scalable and integration-friendly," said CSIRO scientist Dr Zhao Jun Han, who was co-author of the report published in *Nature Communications*. "Our unique technology is expected to reduce the cost of graphene production and improve the uptake in new applications."

GraphAir transforms soybean oil – a renewable, natural material – into graphene films in a single step. With heat, soybean oil breaks down into a range of carbon-building units that are essential for the synthesis of graphene. "Our GraphAir technology results in good and transformable graphene properties, comparable to graphene made by conventional methods," said co-author Dr Dong Han Seo of CSIRO.



CSIRO scientist Dr Dong Han Seo holds a piece of graphene film.

The team also transformed other types of renewable and even waste oil, such as those left over from barbecues or cooking, into graphene films. "We can now recycle waste oils that would have otherwise been discarded and transform them into something useful," Seo said.

The potential applications of graphene include water filtration and purification, renewable energy, sensors, personalised healthcare and medicine. As graphene also has excellent electronic, mechanical, thermal and optical properties, its uses range from improving battery performance in energy devices to cheaper solar panels.

How Maternal Malaria Reduces Foetal Growth

The discovery of why malaria in pregnancy leads to an increased risk of low birth weight babies could enhance the prospects of neonatal survival in the 85 million pregnancies exposed to malaria globally every year.

Lead researcher Dr Philippe Boeuf of the Burnet Institute said that low birth weight is the main risk factor in about 80% of neonatal deaths. Low birth weight children are also at a higher risk of intellectual development issues, and are more susceptible in adulthood to chronic diseases such as diabetes.

"Before now, no one understood the link between being infected with malaria in pregnancy and having an increased risk of delivering a low birth weight baby," Boeuf said. "But we've identified the first mechanism that links the two, and this gives us the opportunity to try to improve foetal growth, and therefore, birth weight. Because low birth weight is the main cause of neonatal death, if we improve the birth weight, this could have a significant impact on neonatal survival, and allow a healthier adult life."

The study, published in *BMC Medicine*, demonstrates that inflammation caused by malaria disrupts a signalling pathway called mTOR. This impairs the capacity of the placenta to transport amino acids from maternal blood to the foetus – a major determinant of foetal growth and therefore birth weight.

The focus on mTOR gives scientists the opportunity to design interventions to promote its activity in order to restore the transport of nutrients and therefore improve neonatal survival and adult health.

"There have been quite a few trials of nutritional supplementation of malaria-exposed pregnant women that had relatively modest impact on birth weight. We think that's because those interventions haven't been targeted specifically at mTOR," Boeuf said.

"The view of most of these interventions has been, well, these women and/or their foetuses are not getting enough nutrients. Therefore, if we give mothers dietary supplements, that should improve birth weight, but results have largely been inconsistent."

"The approach we are taking is, OK, we know that mTOR inhibition appears to be a driver of low birth weight, so let's research ways to activate mTOR, and those that show any effect, we'll take further and hopefully to implementation."

Boeuf said the next step is to test a range of mTOR activators that are safe to take during pregnancy, initially in vitro, and then eventually in a clinical trial in Papua New Guinea, where low birth weight is highly prevalent and 5000 babies die each year in their first month of life.

Boeuf says that the research findings could also be relevant to inflammation in pregnancy caused by other pathogens.



Piotr Marcinski/Adobe

The Drugs Don't Work

Non-steroidal anti-inflammatory drugs (NSAIDs) used to treat back pain provide little benefit but cause side-effects, according to a systematic review by The George Institute for Global Health. The research, published in the *Annals of the Rheumatic Diseases*, found that only one in six patients treated with NSAIDs achieve any significant reduction in pain.

Previous work by The George Institute has questioned the effectiveness of other medicines used to treat back pain, finding that paracetamol is ineffective and opioids provide minimal benefit over placebo. Most clinical guidelines currently recommend NSAIDs as second-line analgesics after paracetamol, with opioids coming at third choice.

Lead author A/Prof Manuela Ferreira says the study highlights an urgent need to develop new therapies to treat back pain, which affects 80% of Australians during their lifetime. "Our results show anti-inflammatory drugs actually only provide very limited short-term pain relief," he says. "They do reduce the level of pain, but only very slightly, and arguably not of any clinical significance. When you factor in the side-effects, which are very common, it becomes clear that these drugs are not the answer to providing pain relief to the many millions of Australians who suffer from this debilitating condition every year."

The team at The George Institute examined 35 trials involving more than 6000 people, and found that patients taking anti-inflammatories were 2.5 times more likely to suffer from gastrointestinal problems such as stomach ulcers and bleeding.

"Millions of Australians are taking drugs that not only don't work very well, they're causing harm," said Dr Gustavo Machado of The George Institute and The University of Sydney. "We need treatments that will actually provide substantial relief of these people's symptoms. Better still, we need a stronger focus on preventing back pain in the first place. We know that education and exercise programs can substantially reduce the risk of developing low back pain."

Nose Gene's Role in Muscular Dystrophy Onset

A genetic change discovered in babies born without a nose could help to prevent a debilitating and incurable form of muscular dystrophy that affects teenagers and adults.

An international research team discovered that mutations in a gene called *SMCHD1* can cause a rare syndrome called boomerang microphthalmia syndrome (BAMS), in which the nose fails to form during embryonic development. The researchers made the connection that *SMCHD1* is also faulty in people with an inherited form of muscular dystrophy called facioscapulohumeral muscular dystrophy type 2 (FSHD2), an incurable condition that causes muscle wasting in teenagers and young adults.

Dr Kelan Chen of the Walter and Eliza Hall Institute (WEHI) said that the research built on the team's earlier discovery of how FSHD2 is caused when *SMCHD1* is defective and no longer functions as it should. "We found that FSHD2 is caused when the protein *SMCHD1* is damaged and can no longer function normally," Chen said.

"We were amazed to discover that in children with BAMS the opposite happens - the nose fails to develop in instances where

SMCHD1 is activated. This is really exciting because it gives us clues about how to design medicines that boost *SMCHD1*'s activity to protect the body from the development of FSHD2," Chen said.

A/Prof Marnie Blewitt of WEHI said that the team had already taken the first step towards developing medicines that could halt the progression of FSHD2. "We hope that this medicine could be used to treat people who know that they carry a defective form of *SMCHD1*, before the muscle wasting commences," she said. "FSHD2 does not commonly cause symptoms until gene carriers are teenagers or young adults, so there is a very good opportunity to intervene."

"This approach is also relevant to FSHD type 1 (FSHD1) patients, as defective *SMCHD1* is associated with a more severe disease, suggesting that boosting *SMCHD1* could treat all sufferers of FSHD1 and FSHD2. We are hopeful that our discovery could lead to the development of therapies for FSHD and perhaps even prevention of a currently untreatable disease," she said.

The research was published in *Nature Genetics*.



Bridle nail-tailed wallabies were presumed extinct before being rediscovered in the 1970s. Two isolated captive breeding colonies are their current salvation.

Credit: Bernard DUPONT CC BY-SA 2.0

A Price for Wildlife

GEORGE WILSON

Can market-based incentives and private ownership of wildlife remedy shortfalls in government funding for conservation?

Half of the world's mammal extinctions in the past 200 years have occurred in Australia. Lists are getting longer, and threats from predators and habitat loss are getting worse.

Species such as brush-tailed rock wallabies are retreating along the eastern seaboard. The status of bridle nail-tailed wallabies, which were presumed extinct then rediscovered in the 1970s, remains perilous. Two isolated captive breeding colonies in which they are locally overabundant are their current salvation, but more are needed.

Bettongs have been most seriously hit, with massive reductions in their range in Australia. Predator-free breeding colonies enable them to continue, but these need to be replicated across the country.

The distribution of kiwi has contracted similarly in New Zealand. Some species are resilient in a limited number of predator-free environments.

Koalas are now listed as vulnerable in Queensland and New South Wales, and are absent from many areas such as the ACT, yet in parts of Victoria they are so overabundant that they're damaging their habitat and starving.

The northern hairy-nosed wombat declined to 35 animals in an isolated colony, making it the most endangered largish

mammal in the world. Although its numbers are now increasing, only one additional colony has been established. Many more should be propagated across its range.

The numbat has retreated across southern Australia to two isolated pockets in Western Australia. Breeding colonies in predator-free environments exist in four locations, but many more are needed.

Federal and state government programs in Australia and New Zealand already collaborate with research institutions and philanthropic organisations to address some of the causes of these problems. In recent years, non-profit organisations such as Bush Heritage Australia and the Australian Wildlife Conservancy have made major contributions to the reserve network, species conservation and support for Indigenous communities, but they do not have the funding or capacity to deal with the problems at the scale that is necessary.

However, most species losses have been on private lands, so relying on the reserve network alone won't fix the issue. Changes need to be made to government policy to give private landholders control over the management and ownership of vulnerable wildlife on their lands. These landholders can help protect vulnerable wildlife by assisting recolonisation from locally overabundant sources and giving them a home on private land.

The value of hunting and meat production from wildlife continues to be an incentive for habitat conservation for wildlife elsewhere in the world.

Credit: Michael Johnson, US Fish and Wildlife Service



... landholders should be able to take up wildlife property rights and use market economics and investments to support their conservation activities.

Altruism and philanthropy are currently the only drivers that motivate landholders to engage in wildlife conservation. As a result, only 1% of the conservation estate is on private land. Thus the private sector needs to be given incentives to increase this proportion. Bringing more land into the reserve network is essential to increasing the habitat available not only for threatened species but wildlife more generally.

Australian policies on wildlife conservation have been based on the notion of wildlife protection within pristine parks and non-use of nationalised wildlife on land outside the parks. The policy is consistent with the London Convention of 1933, which establishes the ownership of wildlife by governments, with exemptions varying between jurisdictions regarding common animals defined as pets, as pests, as well as a form of pseudo-ownership by zoos.

The London Convention applied to much of colonial Africa, but another approach emerged after a wildlife conference at Arusha in 1961. A resolution was passed that emphasised the importance of planned utilisation of wildlife as a renewable natural resource to enable wildlife to compete with agriculture.

The southern Africans adopted these ideas and added the principles of proprietorship, subsidiarity and price. Where fences were constructed to establish proprietorship, govern-

ments began transferring wildlife ownership and decision-making to the private sector. Landholders managing large charismatic wildlife were able to benefit financially from tourism, hunting and meat production. Innovation, competition and more wildlife resulted.

The net result has been that the contribution of private lands to conservation expanded to 17% of the area of South Africa, while the National and Provincial Park network remains at 6%, a figure that includes the vast Kruger National Park.

There have been some problems with the changes, particularly in recent years. The unethical practice of breeding semi-tame lions to be shot at close quarters – so-called canned hunting – has damaged the image of hunters globally and the earning capacity of South African trophy hunting in particular. Similarly, the breeding of unusual colour variants of species such as “ivory springbok” to satisfy trophy collectors is criticised strongly by many wildlife ecologists and conservationists.

In other parts of the world, the value of hunting and meat production from wildlife continues to be an incentive for habitat conservation for wildlife. In Scotland the value of game species such as red deer and grouse enables private lands to withstand economic pressures to convert them to pine forests and sheep grazing. In North America, deer and duck habitat is protected on a vast scale by hunters who invest hundreds of millions of dollars per year to sustain their sport. Also in North America there are some 500,000 bison on private property as meat producers. In contrast there are less than 20,000 found in national parks and state reserves.

Can these experiences be a model for the conservation of smaller, less charismatic species in Australia and New Zealand that have no value as game animals? Would more landholders participate and the area in private conservation increase area above 1% if they had proprietorship and the opportunity to profit?

A proposal published in *Conservation Letters* (<http://tinyurl.com/zjc228a>) has called for trials to test this question and enable non-consumptive trade of live animals for assisted recolonisation. The proposal is that landholders should be able to take up wildlife property rights and use market economics and investments to support their conservation activities. They might possibly even make a profit by on-selling the progeny to other like-minded participants while increasing overall numbers and expanding species distributions off-reserves. Fences that establish protection from introduced predators also enable proprietorship.

The steps in the proposed process include identifying locally overabundant populations as sources of supply; enabling entrepreneurial private landholders to create the demand; and bringing the two together through an internet-based market platform. Careful planning would include mechanisms for controlling predators, habitat management and safe procedures for assisted recolonisation itself.

The government's role would be as the regulator. Leases would be provided to landholders to hold wildlife and to permit movement after consideration of genetic issues. Governments would also set animal welfare codes of practice and monitor the scale of the trade. Later on, biobanking and innovative financing systems modelled on the European Wildlife Bank and NatureVest from The Nature Conservancy could be incorporated into the trial.

The proposal would focus on charismatic vulnerable species, and stimulate altruistic and proprietorial investment. For example, landholders offering rural retreats do not currently have native animal options. They invest in ponies, racehorses, alpacas and heritage breeds of cattle, for instance, but not threatened Australian species. The proposal is that they be given the option to make a profit or at least subsidise their costs by breeding threatened species.

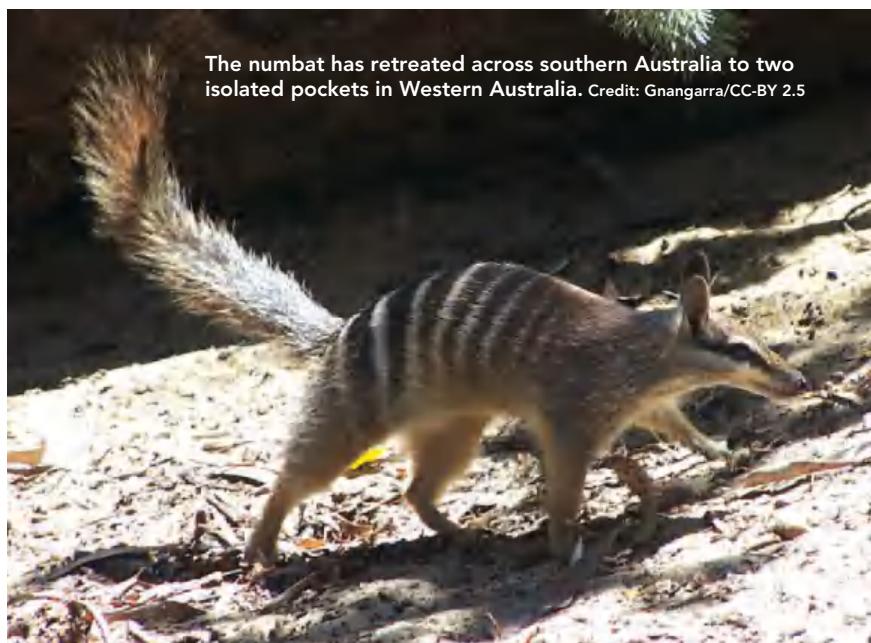
Koalas from Victoria, burrowing bettongs from the Arid Recovery conservation reserve in South Australia, eastern bettongs from the ACT, brush-tailed rock-wallabies from various zoos and breeding enclosures, and bridle nail-tailed wallabies from the Scotia wildlife sanctuary in the Murray–Darling Basin are potential wildlife sources subject to further consideration and approval. There are a number of others.

Some potential criticisms and risks associated with the project are that it is commodifying nature, and is expanding the economic paradigm that caused the decline and demise of wildlife in the first place. Related to this concern is the belief that deriving financial benefit from Australian wildlife is unethical. These sentiments are felt most strongly with animals that are cute and cuddly. They lead to strong emotions and political pressure that often clouds rational ecological and economic decisions.

However, time is running out for vulnerable species on lands transformed by agriculture, other human activity and rampant feral animals. Relying on the intrinsic value of wildlife is not working to reverse extinction trends. The scale of need is far larger than current investments.

With a few exceptions, vulnerable native mammals and birds in Australia and New Zealand remain nationalised assets external to the economy, and hence their continued existence is usually left to the government to manage and fund. Consequently, they remain a priceless yet commercially valueless asset managed by small bands of dedicated staff that are largely funded (inadequately) by governments.

New models are needed to address the problem. Microeconomic reform, economic liberalism and enhanced competition have led to improvements in telecommunications, transport, banking and biomedical science. Following the end of government ownership there have been major advances in efficiency and innovation in those sectors of the national economy. Such reforms have not yet been applied to the management of wildlife, which is still dominated by governments.



The numbat has retreated across southern Australia to two isolated pockets in Western Australia. Credit: Gnangarra/CC-BY 2.5

If a trial is successful, a new industry could be established that taps into a resource that is not being used efficiently. The lack of strong commercial incentives is unlikely to lead to the same levels of conservation of wildlife and habitats off-reserves that has occurred in southern Africa, but proprietorship coupled with altruism could lead to improvements above the current 1% and larger numbers of animals spread more widely. It would build on the economic value that wildlife already has in some Australian jurisdictions in limited circumstances, such as in zoos and as pets. It would drive economic expansion and encourage innovation.

Ultimately, all that is required is to deregulate correctly and let the market establish itself. Governments would cease to be the sole proprietor of native wildlife, as is appropriate in a mixed economy.

George Wilson is Honorary Professor at The Australian National University's Fenner School of Environment and Society, and the principal of Australian Wildlife Services.

Echidnas Have a Nose for Ecological Engineering

CHRISTINE COOPER

Activity loggers have revealed that echidnas turn over 200 cubic metres of soil each year, making them one of Australia's most important remaining ecosystem engineers.

To meet their energy and water needs, short-beaked echidnas (*Tachyglossus aculeatus*) dig to find around 40,000 ants and termites daily. In the process they turn over, or bioturbate, large amounts of soil.

New, custom-built miniature activity loggers have enabled us to show that a single echidna can move about 200 cubic metres of soil per year; this is the equivalent of an Olympic-sized swimming pool for every 12 echidnas. Echidnas are therefore important bioturbators; they break

up and loosen the soil, improve water penetration, reduce run-off and erosion, and incorporate organic matter into the soil profile.

Since many of Australia's other digging mammals – such as bettongs, potoroos, bilbies and other bandicoots – have suffered dramatic declines in their distribution and abundance since European settlement, the widespread echidna is vital to maintaining ecosystem health throughout Australia. However, warmer temperatures associated with human-induced climate change might impact on the extent of their important ecosystem function.

Echidnas are remarkable mammals. They are monotremes, which means they lay eggs like reptiles but have hair and feed their young on milk like other mammals.

Marsupial and placental mammals diverged from monotremes 170 million years ago, so monotremes represent an ancient lineage of great general interest to scientists. There are five living monotreme species: the Australian platypus (*Ornithorhynchus anatinus*), three long-beaked echidnas (*Zaglossus*) in New Guinea, and the short-beaked echidna found in Australia and New Guinea.

The short-beaked echidna is the most widespread Australian mammal, occupying all major terrestrial Australian habitats from snow-covered alpine areas to hot, dry deserts. Due to the protection



The hind feet of echidnas are so modified for digging that they are rotated and point backwards.



Echidnas move in the wild at an average speed of 1.3 km/h, with a maximum speed of only 2.3 km/h.

offered by its sharp spines, introduced predators such as cats and foxes have not had the impact on echidnas they have had on other native Australian mammals.

Echidnas remain relatively common throughout Australia, and this, together with the large amounts of soil they move while foraging, mean they are important ecosystem engineers throughout the continent, maintaining bioturbation and enhancing ecosystem function where the impact of other digging mammals is now limited or entirely absent over much of the Australian landmass.

As well as having a curious mammalian reproductive strategy – females lay an egg that they carry in their pouch for about 11 days before it hatches – short-beaked echidnas have other highly unusual characteristics. They have a much lower resting body temperature than other mammals (only 30°C compared with 35°C for a kangaroo or 37.5°C for a human); their body temperature is also quite variable, and their metabolic rate is only 22% as high as an equivalent-sized mammal.

Echidnas also have an unusual anatomy, partly as a consequence of their evolutionary history and partly as they are adapted to a digging lifestyle. Their shoulders and hips have retained some primitive reptilian characteristics, and they have a sprawling gait and short, stout limbs that generate power when digging. Their hind feet are so modified for digging that they are rotated and point backwards!

Observations of these characteristics raise questions about how these structural and physiological features impact on the echidna's ability to move around in their environment, how their movement is impacted by seasonal weather changes, and how much they dig.

The widespread availability of miniature electronic devices for applications such mobile phones and fitness trackers has changed the way we can study animals in their natural environment. We can now collect data on the private lives of wild animals without having to observe them directly, which might influence their behaviour. This means that it's now

possible to remotely investigate questions about a particular species' biology, and also about its interrelationships with the broader ecosystem. Miniature custom-made activity trackers glued onto the spines of echidnas provided us with three values concerning echidnas' movements – pitch, roll and yaw – up to 200 times per second for a week in summer and again in spring. Small GPS units provided information about the echidnas' location, and radio transmitters enabled them to be re-located to retrieve the logged data.

From these data we determined when and where echidnas were resting, walking and digging. Their rolling gait even allowed for the identification of individual steps, providing a detailed insight into the echidna's day-to-day activity, movements and biomechanics, and how they survive in, and impact on, their environment.

We found that echidnas in the wild moved at an average speed of 1.3 km/h, with a maximum speed of only 2.3 km/h. These slow movements are due to the structural constraints of the echidna's

short, powerful legs. While these provide the mechanical force to dig into soil and even termite mounds, they limit the rate and particularly the length of their steps, thus reducing their walking speed. Indeed echidnas have the shortest relative stride length of any mammal.

The structural constraints of the limbs forces echidnas to change their speed in an unusual way. To move faster, most mammals take longer rather than quicker steps, but echidnas can't increase the length of their steps sufficiently due to the structure of their short legs, so instead they must take more,



New technology has changed the way we study the biology of native animals such as this echidna.

faster steps. This means that echidnas can't move particularly quickly, but their armour of sharp spines protects them from predators. Other mammals such as armadillos and pangolins that have also traded off speed for an improved ability to dig are also armoured; it is not necessary to run quickly if predators can't eat you.

During the hot Western Australian summer, when temperatures reached 45°C during the day, echidnas were nocturnal. They sheltered in burrows, caves, logs, and under leaf litter through the heat of the day, and then at night "sprinted" at their top speed to foraging sites, where they would dig for ants and termites before returning to their shelters after 3 hours of activity.

In spring, when it was 25°C cooler, echidnas were sometimes active during the day, and they wandered between retreats and foraging sites at a more leisurely pace. Hot weather constrains their foraging to more favourable periods at night, while in milder conditions there is more time suitable for activity.

Remaining inactive during temperature extremes makes it easier for echidnas to maintain their low body temperature and saves water, and also aligns their foraging to times when their food is most available. Termites are closer to the soil surface when temperatures are mild, and retreat deeper underground when it is very hot or cold.

Despite the limitations of their limbs and their low metabolic rates, echidnas cover large distances each day of 2.7 km in summer and 3.6 km in spring, moving to and foraging at widespread feeding sites. Echidnas move further than expected for a similar-sized mammal, reflecting the sparse and patchy availability and low energy density of their insect prey.

Termites and especially ants are difficult to digest as their tough external skeletons are made of chitin, a typically indigestible protein. They also use chemical and physical defences to deter predators, so the length of an echidna's feeding bouts are limited by the soldiers that defend the colony.

By licking up ants and termites with a long tongue coated with sticky saliva, echidnas also ingest dirt when feeding, which further reduces the total energy content of a meal. Echidnas must therefore forage widely to find sufficient food to meet their daily requirements.

Echidnas dig up an area of 0.03–0.04 km²/day, moving about 0.56 m³ of soil in this time. This digging, combined with the continent-wide distribution of echidnas and their relative abundance, means that they are one of Australia's most important remaining ecosystem engineers. Their digging plays an important role in improving ecosystem health by enhancing the structure and fertility of the soil. This role used to be shared by a multitude of digging mammals, but various threatening processes, such as introduced predators, land clearing, increasing aridity, changed fire regimes and introduced herbivores have reduced them to such low levels – or driven them locally or even globally extinct – that their bioturbation is no longer sufficient to maintain this ecosystem function.

Despite their current high digging rates, reduced activity during periods of high temperature may mean that echidnas' digging, and therefore their role in providing this ecosystem service, may be reduced with human-induced global warming. As temperatures increase, the energy needed to keep warm may decrease, so echidnas may need to find less food. Food availability may also decrease, and time with sufficiently low temperatures for activity may be impacted, together leading to less digging.

It remains to be seen how the role of echidnas in maintaining Australian ecosystems continues in an ever-changing environment.

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OMG

Oz Mammal Genomics

SALLY POTTER & MARK ELDRIDGE

A large project to sequence the genomes of Australia's mammals will provide the first complete picture of their interrelationships and evolutionary history – and aid their conservation.

Australia and its surrounding islands contain a significant proportion of the world's mammalian diversity, including the only monotremes (egg-laying mammals) as well as a great diversity of marsupials (pouched mammals) and many eutherian mammals such as bats and rodents. More than 300 terrestrial mammalian species are native to Australia, and 87% of these are found nowhere else. This level of unique biodiversity brings value to Australia at economic, social and scientific levels.

Australia's unique biological diversity is a result of the continent's long-term isolation. Over the past 40 million years the Australian continent has been completely isolated from other landmasses and has been drifting slowly northwards as a giant antipodean ark. This period of isolation has allowed much of our fauna to evolve, diversify and adapt independently of other continents.

For example, bats have a long evolutionary history in Australia, with multiple lineages independently colonising the continent from Asia and potentially also from South America before radiating into many unique species. Rodents have also invaded from Asia in two waves over the past five million years, resulting in the rapid evolution of diverse native species. Thus, Australian mammals provide many different answers to the question of how to survive and even thrive over the long-term on this increasingly arid continent.

The conservation of Australia's fauna is not only important ecologically but also for the Australian tourism industry. Iconic native mammals like the koala and kangaroo are a major attraction for international travellers and so the conservation of our unique biodiversity is also economically important.



From a scientific perspective, the marsupials provide an important biological comparison to other mammalian groups, including how their physiology, ecology, reproduction, immune systems and genes function and have evolved.

Australia's isolation has also meant that recently introduced species – especially rabbits, cats and foxes – have had a major negative impact on our mammal fauna, unlike other continents. Australia has the highest rate of mammalian extinctions in the world, with ~30 species becoming extinct over the past 200 years. In addition, 21% of our current terrestrial mammals are threatened. Humans have caused this through the introduction of feral animals, clearing of habitat, farming, and changed fire regimes. Currently, 62 Australian terrestrial mammal species are on the International Union for Conservation of Nature's Red List as Threatened, and another 39 species are listed as Near Threatened.

The extinction of mammal species in Australia is continuing apace. This has had profound consequences on the environment, and necessitates ongoing conservation efforts at a species and landscape level.

Genetic information has been a vital tool in conservation programs for Australian mammals over the past few decades, providing insights and guidance into captive breeding efforts and wild population management. Recent advances in DNA technology, along with diminishing costs, have now dramatically expanded the genetic information we can obtain. We have entered the genomic era, where instead of looking at genetic information from a small number of genes we can now access information across thousands of genes and even the entire genome of each species.

This gives greatly increased understanding and clarity to questions such as the relationships between individuals, the discovery of species, refining boundaries among already named species, and the evolutionary history of populations and species over both recent and ancient timescales. It can also yield important insights for conservation management, such as genetic predictions of which Tasmanian devils (*Sarcophilus harrisii*) are more likely to survive the spread of contagious facial tumours.

To take advantage of these scientific advances, a consortium of museum, university and CSIRO scientists, as well as government agencies and non-government organisations have come together to form the Oz Mammal Genomics (OMG!) Consortium. With a \$1 million investment from BioPlatforms Australia and co-funding from many participating institutions, the

Consortium aims to use genomic technology to improve our understanding and use of Australian mammals in science, as well as to enhance their conservation. This funding will enable researchers to collaborate and share valuable resources to address several major goals.

The major advantage of next-generation sequencing technology is the ability to economically and efficiently sequence whole genomes. While the human genome project took decades and hundreds of millions of dollars to complete utilising many laboratories across the world, genomes can now be sequenced in a few months in a single facility and cost only thousands of dollars.



Bandicoots such as *Perameles* (pictured here) are a highly distinct evolutionary lineage within Australian marsupials.

While several high quality genomes are available for bats and rodents, among Australian marsupials we currently only have genomes for the tammar wallaby (*Notamacropus eugenii*) and Tasmanian devil. These genomes have already provided valuable insights into gene evolution, organisation and function, as well as disease susceptibility and population history. Genomes from several other Australian marsupial species are currently being sequenced, including the koala (*Phascolarctos cinereus*).

A priority for the OMG Consortium is to produce a high-quality marsupial reference genome to anchor future genomic studies and to improve the availability of genomic resources across the diversity of Australian marsupials. In particular, the Consortium will be sequencing the genome of the fat-tailed dunnart (*Sminthopsis crassicaudata*) as it's a model marsupial species frequently used in laboratory studies and has the ancestral marsupial arrangement of $2n=14$ chromosomes. Other priority species include a representative bandicoot (*Isoodon* or *Perameles*), which is a highly distinct evolutionary lineage within Australian marsupials, and a representative of the chromoso-

mally diverse genus *Petrogale* (rock-wallabies), which is the focus of ongoing work on chromosomal speciation and includes numerous species of conservation concern.

Another major goal of OMG is to use a genomic approach to definitively and comprehensively establish the evolutionary relationships among Australia's terrestrial mammals. Our current knowledge of how native marsupial, rodent and bat species are related is limited and patchy. Recently extinct species are usually not included, and relations among extant species are often unresolved as they are typically based on data from only a few genes.



The fat-tailed dunnart (*Sminthopsis crassicaudata*) is a model marsupial species that's frequently used in laboratory studies, and has the ancestral marsupial arrangement of chromosomes.

However, recent technological advances in genomics will enable OMG to generate DNA sequences from thousands of genes from each of the ~300 Australian terrestrial mammal species as well as some closely related species from New Guinea and nearby islands. This will provide a significantly more robust and definitive understanding of their relationships and evolutionary history, and a framework for comparative analyses of their extinction risk.

One of the major advantages of a genomic approach is the ability to use fragmented DNA, which will enable us to access the huge number of mammalian skin and skull specimens housed in Australia's natural history museum collections. This will enable, for the first time, recently extinct species such as the thylacine, pig-footed bandicoot, white-footed rabbit-rat and other rare species that are only known from a handful of museum specimens to be incorporated into the analysis. This will provide the first complete picture of the interrelationships and evolutionary history of Australia's mammals, as well as provide a backbone for future studies.

We anticipate that this comprehensive coverage and unprecedented genetic power will lead to the clarification of species boundaries within many previously problematic species complexes, and so lead to the identification of new species that in many cases have remained undetected in museum collections. For example, in 2014 a new mammal species was discovered in northern Australia, Wilkins' rock-wallaby (*Petrogale wilkinsi*), which was first recognised from genetic studies of material from Australian museum collections. This discovery and others like it suggest that many new species await discovery, even in relatively well-known groups such as mammals. The identification of these hidden or cryptic species is an essential first step to their effective conservation.

A major aim of the OMG project is to provide detailed and state-of-the-art genetic information to assist in the on-ground management of threatened Australian mammal species. The Consortium includes state and territory wildlife management agencies, as well as non-government land managers (e.g. Arid Recovery, Australian Wildlife Conservancy, Bush Heritage Foundation) and zoos that are

actively managing threatened mammal species through captive breeding, translocations and reintroductions.

Using genomic data, OMG will be able to assess the genetic impacts of habitat loss and fragmentation, population isolation and inbreeding on mammal species, as well as guide the selection of animals for reintroductions and captive breeding, and assess the effectiveness of these programs in maintaining genetic diversity. Some of the priority species that will benefit include the greater bilby (*Macrotis lagotis*), greater stick-nest rat (*Leporillus conditor*), burrowing bettong (*Bettongia lesueur*) and western barred bandicoot (*Perameles bougainville*).

The OMG Consortium comes at an opportune time to provide increased scientific power to the conservation of our threatened mammals, as well as to increase public awareness of Australia's unique mammal fauna and genomic capabilities. The data generated by OMG will provide an extensive and valuable research resource that will be used for decades to address fundamental questions of species biology, understand how the extraordinary mammals of Australia evolved, and hopefully turn the tide of mammalian extinctions in Australia.

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The initial opening of the Great Rift Valley in south-western Tanzania could have been a key factor that led to the evolution of fungus-farming behaviour in termites. Credit: E. Roberts



Were Termites the World's First Farmers?

ERIC ROBERTS & CHRISTOPHER TODD

New trace fossils from the African Rift Valley reveal evidence for the origins of agriculture, not by humans but by insects.

For the average person, the very utterance of the word “termite” calls to mind the tiny critters that eat away the timber supports of your home. However, this negative association ignores the fact that termites are actually among the most biologically diverse and ecologically important groups of insects. In fact, termites are responsible for as much as 90% of the decomposition of dry wood and nutrient recycling in certain ecosystems, and they have recently been recognised for their role in creating biodiversity and bioproduction hotspots in African savannahs.

We have now stumbled onto a remarkable fossil discovery that highlights the evolutionary importance of these creatures while also providing an interesting parallel with human development. Over the past 15 years, our team of palaeontologists and geologists have been working in Tanzania, in a little studied portion of the East African Rift System in an effort to document the origin and evolution of vertebrates in Africa. This project, the Rukwa Rift Basin Project, initially focused on the discovery

of new dinosaur fossils, but a series of unexpected discoveries pushed the project in many other weird and wonderful directions.

Among the highlights of this work was the discovery of previously unknown fossiliferous sedimentary deposits that helped us to better understand the timing and origin of the East African Rift System itself. In one of these units, dated to ~25 million years old, our team discovered a bounty of new fossils, including the oldest known fossils of apes and Old World Monkeys from Africa. Then, last year, our team discovered an even more unusual series of fossils that provided us with compelling evidence for the origin of agriculture – albeit not the origin that most would expect.

Although agriculture is typically considered a uniquely human endeavour, what we found in these 25 million-year-old rocks was not human or even anthropoid, but termite in origin. The fossils in question are what are known as trace fossils, which preserve evidence of the behaviour of organisms rather than the organisms themselves.

It was in a tectonically uplifted cliff of sandstone that we found the remains of several beautifully preserved ancient termite nests. This is not an unexpected discovery because fossil termite nests are relatively common in rocks going back to the Mesozoic age of dinosaurs. What was unusual was the preservation of a series of specialised chambers with bizarre pebbly, spaghetti-like structures that closely resembled the fungus gardens constructed by fungus farming termites (*Macrotermitinae*).

However, the fossil record of fungus farming termites only extends back to ~7 million years ago. Using a combination of analytical approaches, our team of specialists was able to confirm that the fossils were indeed ancient fungus gardens.

With this knowledge in hand, we worked together with molecular and evolutionary biologists to recalibrate molecular clock estimates used to estimate the timing of symbiosis between termites and fungi. In other words, these fossils provided strong evidence to support long-held hypotheses that the origin of fungus farming and the symbiotic relationship between termites and fungi – first occurred ~31 million years ago in a central African forest.

This date roughly coincides with the initial opening of the East African Rift, an event that is believed to have significantly altered the African landscape. Such a dramatic environmental shift, and the initial transition from forests to savannahs and grasslands, could have been a key factor that led to the evolution of the fungus farming behaviour in termites and indeed, the origin of agriculture.

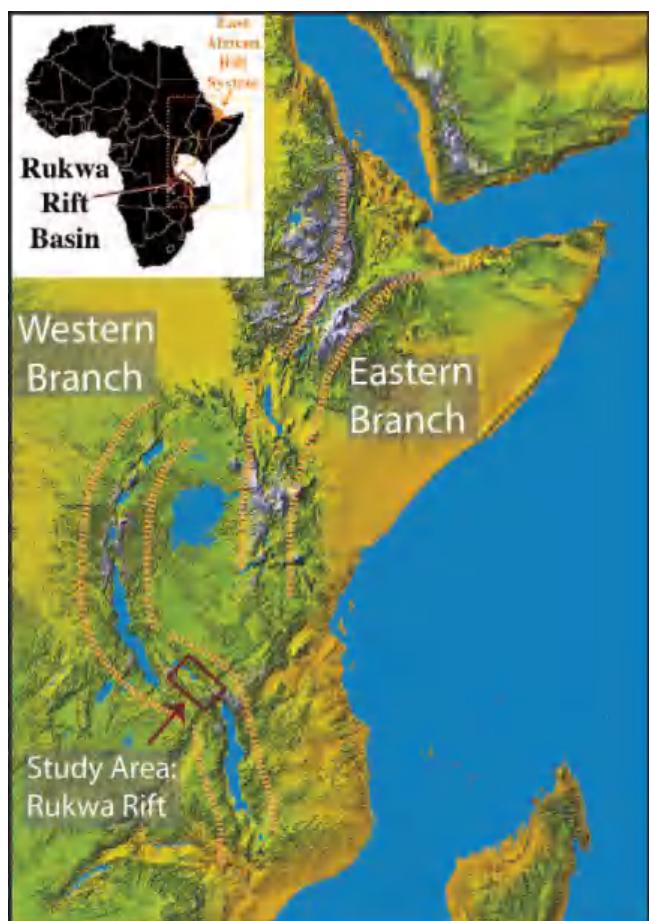
The History of Agriculture

The development of human agriculture only occurred 10–12,000 years ago in the Fertile Crescent (what is the modern Middle East) during a period known as the Neolithic Revolution. This was the first time that humans deviated from their nomadic lifestyle and began to intensively cultivate the land around them and domesticate livestock. This has been argued by many as one of the most important developments in human history, which ultimately led to rapid cultural advancements that followed this time period. Similarly, the evolution in certain insect groups of agriculture, in the form of symbiotic mutualisms with fungi, allowed these groups to occupy new niches and become among the most successful groups in the insect world.

Only three groups of insects have derived mutualisms with fungi for agriculture. These include the ambrosia beetles, the leaf-cutter ants and the Macrotermitine termites. In the case of Macrotermitine termites, who we think constructed these 25 million-year-old fungus gardens in Tanzania, the symbiotic relationship offered the fungi a protected growth environment; in return, the fungi produced food for the termites. This is



A 25 million-year-old termite nest with the remains of a fungus garden preserved inside. Credit: H. Hilbert-Wolf



A map of Great Rift Valley, with the study area in the Rukwa Rift highlighted.

both in the form of degraded plant material and/or enzymes that aid in the breakdown of cellulose, and in the form of fungal biomass.

The termites cultivate the fungi in enormous quantities on a substrate of partially masticated woody plant material.



This modern fungus garden of *Macrotermes natalensis* comprises small spheres of partially digested plant material called mylospheres, from which mushrooms fruit. Credit: J. Korb



This fungus garden from Tanzania dates back to the Holocene (500–5000 year ago). Note the hollow chamber with fungus comb. Credit: E. Roberts

To do this, the termites essentially eat plant material and briefly pass this through their gut before passing it back out and forming the partially digested plant material into a series of small spherical wood pellets called mylospheres. The mylospheres are inoculated with fungus spores to construct the fungus gardens.

While the fungi help to break down the woody plant material in the mylospheres into a more digestible form, they also produce vast quantities of fruiting mushroom bodies that the termites also consume. The mylospheres are consumed by the termites after the fungi in the wood quit producing fruiting bodies and die.

Termites, ants and beetles are the only insect groups known to have evolved such symbiotic relationships with fungi, and estimates on the antiquity of this behaviour range from 24–34 million years ago for termites, 45–65 million years ago for ants, and around 50 million years ago for beetles. Prior to our

discovery, fossil evidence of fungus farming behaviour in any of these groups has been scant, with only two reports indicating that the behaviour could be traced back only as far as 7–10 million years ago in both termites and ants. Other workers, however, had hypothesised that certain trace fossils may record evidence of this behaviour as early as 30 million years ago. Despite the observation of fungus farming in beetles, researchers have yet to find unequivocal evidence to trace back the antiquity of this behaviour.

So where do we go from here? The field of continental ichnology is still in its infancy as a science, and discoveries like the one described here highlight the opportunities that still exist in this field of study. When it comes to searching for such things as the antiquity of fungus farming or other behaviours, maybe we just need to change our search criteria.

Eric Roberts is Head of the Geosciences Department in James Cook University's College of Science and Engineering, where Christopher Todd is a PhD candidate.

Issues with Fossil Preservation

It is because of the selectiveness of the fossilisation process that much of the history of life remains unknown. All living creatures are made of organic material and, unless certain environmental conditions are met, organisms with soft bodies, as well as any evidence for complex behaviours (such as fungus farming), are almost impossible to preserve in the fossil record. Even if preservation occurs, secondary agents of destruction such as erosion, weathering and chemical leaching through groundwater interactions often destroy any evidence before it can be discovered in the field. Therefore, the fossil record is much like a lottery system where there may only be a one-in-a-million chance of preserving something so common, yet so fleeting, as evidence for fungus farming.

Presumed GUILTY

STEPHEN MOSTON & TERRY ENGELBERG

A study of 100 cases of doping in Australian sport has concluded that the system is flawed.

Imagine a criminal justice system based on a presumption of guilt. In this system, prosecutions would be based on evidence with no clear scientific basis, and the defence cannot dispute or in any way question that evidence.

Into that system place a suspect, an otherwise upstanding citizen with no intention of committing any offence. Accuse that person of an offence, which even the prosecution agrees was so utterly inconsequential that no objective harm was done, and that the suspect did not benefit in any conceivable way.

Finally, imagine that the whole system is overseen by an organisation with a vested interest in ensuring a high conviction rate. It's a bit far-fetched, isn't it?

Except it's not. This is essentially the system in place for dealing with athletes suspected of doping. If that sounds like a cynical take on things, John Fahey, former President of the World Anti-Doping Agency (WADA), recently described the system as "a strange set of rules which effectively says if the drug is in your system, guilt is a given and the only room left is to endeavour to reduce the sanction". Forget innocent until proven guilty. This is guilty until proven innocent, and then still guilty.

Doping, defined in a somewhat circular fashion as a breach of anti-doping rules, exists as an offence where the public perception of an offender is in many cases quite different from reality. For example, if you Google "doping" you find images of needles and bulked-up athletes, which is basically what we are supposed

to think of when we hear the word "doping". Popular thinking would suggest that doping is performance-enhanced cheating.

But what about athletes who used a banned substance accidentally, and in such low quantities that they would have obtained literally no performance enhancing benefit? Or what if that banned substance was actually a detriment to performance? How does an athlete in such a scenario prove their innocence? The simple answer: they can't.

An archival analysis of 40 anti-doping cases involving tennis players in 2003–07 found that a prohibited substance was taken to enhance performance in only 13 cases. Most tennis players identified as using prohibited substances were guilty of little more than administrative errors. It was accepted at the independent hearings that there was no intent to enhance performance in 19 of the 40 cases, and no (significant) fault or negligence in eight cases. Nevertheless, sanctions were applied in all cases.

Similar examples are abundant within the literature, each highlighting WADA's doctrine of strict liability, a belief that all athletes found using banned substances are doping cheats, and that harsh sanctions should be enforced in almost all cases. According to WADA, strict liability:

means that each athlete is strictly liable for the substances found in his or her bodily specimen, and that an anti-doping rule violation occurs whenever a prohibited substance (or its metabolites or markers) is found in bodily specimen, whether or not the athlete intentionally or unintentionally used a prohibited substance or was negligent or otherwise at fault.



The Court of Arbitration for Sport has supported adherence to strict liability. The rationale behind such a policy is largely pragmatic, in that it is argued to be more appropriate that the occasional athlete who inadvertently dopes be prosecuted than to complicate matters and potentially allow the real doping athletes a loophole by which they may escape conviction.

This is further demonstrated by the Code's view of the burden of proof, which is "in all cases greater than a mere balance of probability but less than proof beyond a reasonable doubt". This is evidently done to provide maximum legal power to the judicial body and minimal legal power to the athlete. Clearly, the system in place provides insufficient opportunity for athletes to prove their innocence.

"We need to stop pretending sport is clean. It's a noble principle, but in practice? It's entertainment. It's drama."

Gian-Franco Kasper, International Olympic Committee Executive Board

The Case of Maria Sharapova

While anti-doping authorities take a largely sceptical stance on denials of doping, other stakeholders appear more open to the possibility that a denial might be valid. This can be illustrated by the case of tennis player Maria Sharapova. The authorities concluded that Sharapova had concealed her use of the drug Mildronate and was "the sole author of her own misfortune". Specifically:

To none of the medical practitioners or specialists who treated her over 3 years did she disclose the fact that she was taking Mildronate. Her explanation in evidence is that none of them had asked what medication she was taking... There is no document after 2010 in the player's records which relates to her use of Mildronate. Nor was the use of Mildronate disclosed to the anti-doping authorities on any of the doping control forms which Ms Sharapova signed in 2014 and 2015.

The lack of credibility in Sharapova's defence was commented on:

The tribunal is not required to accept evidence which it finds to be wholly incredible. The idea that a professional manager, entrusted by IMG with the management of one of its leading global sporting stars, would so casually and ineptly have checked whether his player was complying with the anti-doping programme, a matter critical to the player's professional career and her commercial success, is unbelievable.

Despite this lack of credibility, many of Sharapova's sponsors, most significantly HEAD, have maintained that Sharapova is an innocent victim of a flawed anti-doping system. Sharapova's public relations efforts have followed the same basic pattern, and while her reputation has been tarnished, there is little reason to believe that this will have any significant effect on her earning potential once her career resumes after her doping ban.

Incredible Athletes (and Some Credible Ones)

Psychologists specialising in the study of criminal denials suggest that believability is the core dimension in which observers (including detectives, judges and jurors) assess denials. Simply put, some denials are more credible than others, and as such are more likely to be believed.

Denials can take many forms, but these can normally be classified into one of two broad typologies: passive and active. A passive denial is one in which the suspect denies the accusation but does not provide any exculpatory detail. An active denial does include exculpatory detail.

Passive denials, in the doping context, can take many forms, including:

- simple denial of charge (e.g. "No, I didn't take steroids");
- denial of knowledge (e.g. "I don't know how that got in my sample"); and
- denial of motivation (e.g. "Golf is a skill sport; no drug will help you putt straight").

Active denials can also take many forms, including:

- denial of offence, where the suspect actively argues that no offence was actually committed (e.g. "I did not take the test because I felt unwell");
- denial of interpretation, where the suspect might claim that an innocent behaviour has been misinterpreted as a doping behaviour (e.g. "I used some pharmacy cold and flu tablets"); and
- denial of causation, where the suspect attempts to shift the blame onto another person (e.g. "I accidentally drank a spiked soda").

In many doping cases, denials are openly ridiculed and are sometimes even compiled into lists of "best doping excuses". Such scepticism is also reflected in the public comments of leading anti-doping figures, who generally disregard anything athletes say in their defence: essentially a variant of "Well s/he would say that, wouldn't s/he?".

While some denials are rather obviously not credible, little is known about how many athletes attempt to deny doping, and how they try to overcome the perception that they are guilty and are simply lying to evade severe sanctions.

Therefore, we recently conducted an archival study of 100 consecutive Australian sanctioned doping cases. In this study, we combined an analysis of official reports of doping sanctions with publicly available data, primarily sourced from media interviews. From this broadly representative sample we identified 23 athletes who had publicly claimed that their doping offence had been either accidental or inadvertent. There may have been more accidental cases in our overall sample but, as the current system encourages acquiescence (don't deny, just accept the sanction), some athletes may have chosen to accept the sanction without attempting any defence.



Yann Caradec CC BY-SA 2.0

Content analysis of the statements made by the 23 athletes revealed seven different defence strategies (i.e. the excuse or explanation the athlete offered to suggest that their anti-doping rule violation was accidental or inadvertent). The numbers and percentages of each strategy use are shown in Table 1.

Table 1. Accidental anti-doping rule violation defence strategies.

Defence Strategies	Number	%
Accidental consumption in nutritional supplement	10	43.5
Banned substance contained in medical treatment	4	17.4
Accidental purchase	4	17.4
Accidental whereabouts violation	2	8.7
Accidental consumption of substances used by a third party	1	4.3
Accidental over-consumption of prescribed medication	1	4.3
Accidental testing violation	1	4.3

Maria Sharapova's 15-month suspension ends on 26 April. Many of her sponsors have maintained that she is an innocent victim of a flawed anti-doping system.

Ten of the cases (43.5%) featured claims that banned substances were present in nutritional supplements, often involving substances purchased over-the-counter. The next two most frequently identified strategies (four cases each) were that the banned substance was present in a medical treatment prescribed by a medical practitioner, or that the purchase of the banned substance was accidental.

Overall, our study shows that athletes who claim to have accidentally or inadvertently doped are placed in a no-win position. They can accept the charge, making them "doping cheats", or they can deny the charge, making them "lying doping cheats". At this moment, there is little to be gained in attempting to claim innocence. Quite how this aligns with WADA's stated aim – "We develop policies, procedures and practices that

reflect justice, equity and integrity" – is, at best, unclear.

It's our belief that anti-doping needs to change to a criminal justice system-style of investigations and prosecutions. Yes, some doping athletes will evade prosecution, but it's far less likely that innocent athletes will be punished. Just as importantly, it might even make some sort of sense, which is clearly not the current situation.

The alternative is to continue with a system where the real winner of a race in 2008 is confirmed in 2016.

Perhaps Gian-Franco Kasper of the International Olympic Committee was right when he recently said: "We need to stop pretending sport is clean. It's a noble principle, but in practice? It's entertainment. It's drama." If that's the view of a senior figure in the sporting world, what exactly are we fighting for?

Stephen Moston and Terry Engelberg of James Cook University's College of Healthcare Sciences are the authors of *Detecting Doping in Sport* (2017, Routledge, UK).

Why Size Matters at Birth

MARIE-JO BRION

A large genetic study has determined why small babies are at greater risk of disease as adults.

There's a longstanding interest in birthweight, with documented examples of its routine assessment in European hospitals as far back as the 1850s. Today, birthweight is an established indicator of an infant's health at birth, but it also relates to a baby's chances of survival and health later in life. As such, measurement of birthweight is almost universally a part of all modern newborn health assessments.

Birthweights vary widely, spanning from 2500–4500 grams within the normal range. Around one in 16 Australians are born in the low birthweight category of less than 2500 grams.

Birthweight is a blunt measure of the overall growth and development of a foetus in the womb. It reflects the accumulation of many biological processes, some of which are known but many of which have simply not yet been identified.

Pre-term births, as well as multiple births, are associated with low birthweight because an early birth or a shared womb limits the extent to which a baby can grow in utero. However, the causes of low birthweight for a full-term infant are not entirely clear.

Parental size, as well as maternal health and behaviour during pregnancy, play a role. In particular, smoking during pregnancy and poor prenatal nutrition can adversely affect the developing foetus and reduce its size at birth. These factors are also linked to lower socioeconomic status, which is a known general risk factor for having a low birthweight infant.

However, these factors can't fully explain differences in infant birthweight. A new study has found that genetics plays a more important role than previously thought.

Genetic Factors Influence Birthweight

Traits like birthweight are influenced by a large number of different genes, most with very small individual effects. Trying to identify these small individual genetic factors is a little bit like looking for needles in a haystack, and it's not uncommon for genetic studies of this type to uncover only a few genetic factors. However, the

larger the study, the better the chances are of uncovering the genes involved.

This is why a team of more than 300 scientists from around the world pooled their resources to compile a study of more than 150,000 individuals born at full term. This is currently the largest-ever study of the genetics of birthweight. The study was co-led by Prof David Evans and Dr Nicole Warrington of The University of Queensland's Diamantina Institute, together with research teams in Exeter and Oxford. It was published recently in *Nature* (<http://tinyurl.com/jay3u8x>).

These kinds of studies are important because they not only discover new genes, but they also implicate biological pathways involved in the trait being studied. In this way, genetic studies of birthweight can provide vital clues about the biology of birthweight, and can identify important processes that are both genetically and environmentally determined.

An example where this is clearly evident is in genetic studies of heart attack. Of the genetic regions that contribute to the risk of heart attack, a number of them affect lipid activity and blood pressure. This points to a general involvement of lipids and blood pressure in the risk of heart attack, which can then be altered by non-genetic means, as is done commonly in the treatment of cardiovascular disease.

The new genetic study of birthweight linked 60 genetic regions to birthweight. The findings confirmed that birthweight is determined by many different biological pathways, including those related to metabolism, growth and development. Specifically, these involved insulin, glycogen, cholesterol and growth hormones.

Armed with their new findings on the genetics of birthweight, the authors of the study were then able to investigate the intriguing relationship between birthweight and adult disease.

Small Babies and Adult Cardiometabolic Disease

Low birthweight correlates with the risk of many different diseases in later life, including cardiovascular disease, Type 2 diabetes,

Dmitry Lobanov/Adobe



asthma, cancer and mental health conditions. A popular theory called the “Developmental Origins of Health and Disease” argues that undernutrition during early stages of development, such as when a foetus is developing in the womb, causes permanent changes to the structure and function of developing tissue and organs. According to this theory, these adverse changes persist in the infant over time, leading to increased risk of various diseases in later life.

The support for the developmental undernutrition explanation stems mostly from correlational studies in humans and animal research. This body of literature is vast, yet many question marks hang over the theory primarily because it is extremely difficult to prove in humans that factors producing low birthweight causally affect the future risk of cardiometabolic disease. Since we cannot experimentally induce inadequate prenatal nutrition in humans, studies have to rely on non-experimental observational data. This makes it very difficult to pin down the exact causal variables in these types of studies. This is particularly the case with nutritional factors and determinants of health, which are hard to measure, highly correlated with one another and difficult to separate.

There are also common confounding variables, such as socio-economic factors, that relate strongly to both size at birth and various aspects of health and disease. This could also potentially account for the observed relationship between low birthweight and disease.

However, the large *Nature* study opens up a new window of insight. The scientists combined their genetic data on birthweight together with data from previous genetic studies of adult traits, including blood pressure, heart disease, Type 2 diabetes and body mass index, and found that many of the genetic factors contributing to birthweight are also contributing to these adult traits.

For some of these traits, such as blood pressure, the genetic correlation with birthweight was very high. This is the first time researchers have found such strong evidence that genetics plays an important role in determining why smaller babies are at increased risk of later cardiometabolic disease.

Genetics Links birthweight and Adult Disease

So what does this genetic link mean? It is not yet fully understood how these genetic factors are having common effects across birthweight and adult outcomes.

The genes could be having different effects on the body at different stages of life. In the study, some of the genetic regions influencing birthweight are involved in insulin signalling, which affects both growth and metabolism. Reduced insulin activity could result in impaired growth during periods of early development, while in adults it could adversely affect metabolic processes that predispose to Type 2 diabetes.

In addition, because a mother and her baby share many of the same genes, it is difficult to know if the correlation between

reduced birthweight and increased risk of disease in later life is due to the baby’s genes alone or the baby’s and mother’s genes combined. The evidence from this recent study seems to point more towards effects that are coming from the baby’s own genes. However, it is also possible that maternal genes affect the intrauterine environment in which the foetus develops.

Either way, the existence of a genetic component in the link between low birthweight and the risk of cardiometabolic disease in later life does not exclude a role for modifiable environmental factors. In general, both genetic and non-genetic factors seem to explain the link between birthweight and adult health.

In short, the new study suggests that at least some component of a baby’s birthweight and their later risk of disease is predetermined by their genetic make-up, and confirms that there are indeed specific biological pathways linking the two. This opens up new possibilities for disease intervention.

While we can’t (yet!) alter our genetics through intervention, we can modify the biological pathways the genetic findings point to. For example, knowing that insulin genes play a role in birthweight and adult health is informative because we can target insulin levels in the body.

What Does This Mean for Small Babies?

Mothers and individuals of low birthweight need not despair. Birthweight is just one of many modest predictors of cardiometabolic disease risk. In fact, by far the strongest predictors of cardiometabolic disease are risk factor levels in adulthood, such as cholesterol and blood pressure in adults. Lowering these risk factor levels in adulthood is highly effective for reducing the risk of heart attack and stroke.

Of course, adult health and behaviours can sometimes be very difficult to target, as lifelong habits are often resistant to change. Reversing disease, once physiological processes have already set in, can also be limited.

Because of these and other challenges, many believe that the impact of traditional approaches for preventing cardiovascular disease has plateaued. In this context, identifying additional areas where improvements in health can be attained, such as in the early stages of life, can add value.

There is already a focus on certain prenatal factors, including adequate nutrition and the overall health of mothers during pregnancy. The genetic findings are now providing new places to look within our complex biology. The hope is that this will improve our understanding of what determines birthweight and how we can improve health outcomes throughout the course of life.

Minimising disease risk from the earliest stages of life could lead to improved health for everyone. However, early interventions to reduce the risk of disease could be particularly important for low birthweight babies.

Marie-Jo Brion is a Research Fellow in Genetic Epidemiology at The University of Queensland.



Genetically modified chickpea plants that express a pro-survival gene derived from Australian resurrection plants (*Tripogon loliiformis*) are more stress-tolerant. This image shows non-GM (left) and GM (right) chickpea plants that had been drought-stressed at flowering by applying half volumes of water for 30 days. This photo was captured after an additional 35 days without watering.

Back from the Dead

BRETT WILLIAMS & SAGADEVAN MUNDREE

Resurrection plants can survive for years in an air-dry state before growing at full capacity when the rain comes. How do they do it, and can this trait be transferred to improve the tolerance of crops to drought, heat, salinity and infection?

Plants require significant amounts of water. On a hot, sunny day some plants replace every water molecule in their body within an hour.

We make cars more fuel-efficient to reduce costs and emissions. Can we make plants more water efficient to save water and get more crop per drop?

Plants can contain as much as 90% water. In contrast, humans contain approximately 60% water. To put the water demands of plants into perspective, if a crop plant loses water to levels equivalent to humans then it will wilt and die.

How Do We Help Plants Tolerate Drought?

A small group of flowering plants can lose up to 90% of their water and remain in that state for months. These “resurrection plants” may hold the secret to improving drought tolerance in crops.

Like the phoenix, resurrection plants are able to dry to an air-dry “ash” state and, upon watering, are “rejuvenated” to start growing at full capacity within 24–72 hours.

Imagine if we could generate crops that can tolerate significant water loss during droughts and then start to grow again when the rains come.

Recently our group found that the cells of an Australian resurrection plant do not die upon drying. Upon watering, existing tissue recovered rather than new fresh tissue generating.

Further research has shown that the cells can survive from months to years when in the dry state. Resurrection plants have even been found “thawed” out and growing after spending hundreds of years frozen in Antarctic ice caps that are beginning to melt due to global warming.

How do the cells in resurrection plants survive in such harsh

conditions? The observation that cells remain alive in resurrection plants when dried has led us to look at the different strategies that plants and animals use to suppress cell death. The details of these analyses have recently been published in *PLoS Genetics* (<http://tinyurl.com/htlsxsw>).

What we found is that the resurrection plant increases the amount of trehalose, a type of sugar that most land plants do not accumulate to great levels. The resurrection plant uses this sugar to regulate programmed cell death pathways.

Programmed cell death is a process that occurs in all organisms. This process decides whether a given cell lives or dies. This occurs during development as well as in response to stress.

In humans, programmed cell death helps the formation of our fingers and toes by telling the cells between our fingers to die while surrounding cells divide and grow to form our digits.

It is thought that programmed cell death helps the organism survive by sacrificing a few cells in a controlled manner that restricts the number of cells from dying uncontrollably.

Since all stresses eventually lead to death, if we can control the decision of programmed cell death pathways it may be possible to generate crops that are tolerant to a range of stresses such as drought, heat, salinity and infections by fungi and other pathogens.

Armed with this new information, can we transfer the survival traits of a resurrection plant to crops?

Feeding a Growing Population

The global human population is currently at approximately 7.5 billion, and is expected to peak at 10 billion in the mid-2050s. To feed this population we must produce the same amount of food in the next 50 years than was produced in the past 10,000 years combined. This equates to almost a 70% increase in agricultural production.

Can we increase our food supplies to meet this demand without devastating the planet?

Although agriculture utilises almost 70% of our global freshwater sources, it takes about 100 times less water to produce 1 kg of plant than animal-based protein. This is because animals need both water directly as well as plants as food. Thus, water required for the production of an animal's plant-based food must be included as part of the water requirements needed to produce animal protein.

Can we survive on plant-based proteins alone? High-protein plants such as legumes

and pulses may provide the answer.

Legumes are plants that produce fruit enclosed in pods. Pulses are legumes, but the pulse refers to the dried seed of the legume. Pulses such as chickpeas, mungbeans, lentils and faba beans are some of the most nutritious foods available and are high in protein, fibre and essential minerals such as iron, folate and other B-group vitamins.

Like all crops, pulses are susceptible to drought and other environmental stresses. Can we improve the stress tolerance of pulses?

Using our observations that trehalose accumulation induces survival pathways, we have transferred a single gene from a survival pathway of an Australian resurrection plant into chickpeas and assessed the plants for stress tolerance. Early glasshouse trials have demonstrated that the genetically modified chickpeas are drought, salinity and heat-tolerant, as well as resistant to the grey mould fungus *Botrytis cinerea* found on strawberries left for a few days outside of the fridge.

The genetically modified chickpeas are also producing larger quantities of higher quality, larger fruit.

Although at the early stages, these experiments demonstrate great potential for the transfer of stress resistance from resurrection plants into crops without affecting growth rates or yields.

In the future, using newly developed gene editing techniques it may be possible to develop non-GM stress-tolerant crops that can continue to yield even in dry environments.

Brett Williams is Vice Chancellor's Research Fellow and Sagadevan Mundree is Director of the Centre for Tropical Crops and Biocommodities at Queensland University of Technology.



Early glasshouse trials have demonstrated that the genetically modified chickpeas are drought, salinity and heat-tolerant, as well as resistant to the grey mould fungus *Botrytis cinerea* found on strawberries. From left to right: Dr Sudipta Das Bhowmik, Prof Sagadevan Mundree, Dr My Linh Hoang and Dr Brett Williams.

The Data Detective

ANN LEDUC

Michael Aitken made his name developing software to detect stockmarket fraud, and now believes he can save the health sector \$20 billion by detecting fraud and waste.

Many Australians invest their savings on the stockmarket, and trust that the stockmarket will give them a fair go. They may not realise that their nest egg is being watched over by technology developed right here in Australia.

Now owned by Nasdaq, SMARTS is the dominant software for market surveillance. It's used by more than 55 national exchanges and regulators as well as 120 international brokers across 50 countries. This is Australian technology helping Mom and Pop investors the world over, and it's only one of four technologies developed under the leadership of a very unconventional academic, Michael Aitken, Professor of ICT Strategy at Macquarie University and CEO of the Capital Markets Cooperative Research Centre (CMCRC). Aitken dedicated his life to making markets fairer and more transparent and, in the process, is reinventing how academics do their work.

Reflecting upon his award of the 2016 Prime Minister's Prize for Innovation, Aitken said he was struck by the similarities between his experience and that of Prof Richard Shine of The University of Sydney, who won the 2016 PM's Prize for Science for his research on cane toads: "Richard pointed out that he was amazed how simple fieldwork could trump sophisticated labs and equipment, and I empathise with his point," he said. "At the heart of my work was the simple recognition that pre-existing theories of how the securities markets worked were quite inadequate, and to rectify the situation I found myself, like Richard, with no choice but to go down to the marketplaces and try and figure out how in fact they operated."



Aitken had second thoughts about approaching the Australian Stock Exchange for fear he was the only academic who didn't actually know how the marketplace operated, and instead found himself welcomed as the first academic to bother to ask such questions. He found himself prodding organised chaos. The markets had been fully automated to make them more competitive, and Aitken was shocked to discover that market design changes, like the introduction of competition or algorithmic trading, were being made without any evidence about what was working and what wasn't. He claims the genesis of SMARTS arose from a very docile statement he made one day that "since the market is fully automated, it might be possible to replay trading circumstances of today, tomorrow". This was met with sneers.

Two of Aitken's students claimed they could write a program if he could get the data from the reluctant exchanges, so he convinced a visionary senior executive in Reuters, Mr Herbie Skeete, to provide it. So extensive was the data at the time that it had to be flown out to Australia on Qantas each month in huge boxes of magnetic tapes.

Five years later, the trio had built a prototype of what subsequently became known as the Thomson Reuters Tick History product, which today ingests two million transactions each second from every securities market in the world and makes it available to commercial clients within 20 minutes. This outcome was important for Reuters as it earns the company approximately \$100 million per annum, but for Aitken the task was more idealistic. He wanted to be able to investigate the impact of market design changes in any market of the world, and he had

the first piece of the puzzle. He founded the Securities Industry Research Centre of Asia-Pacific to deliver the Thomson Reuters data to all academics across Australia and New Zealand.

He now set out to recreate the market, trade by trade, order by order, second by second, and noticed things like prices running up just before takeover announcements – a classic pattern of insider trading.

Notwithstanding this work in market surveillance, Aitken's real quest was for a way to enable evidence-based policy-making in financial markets, a task that remained unsolved until last year when he launched the Market Quality Dashboard (<https://www.mqdashboard.com>). He reached that goal by establishing a partnership between industry and academia through the CMCRC, and in the process built a powerhouse of industry-focused PhDs.

This partnership arose from the realisation that most of Aitken's own PhD studies had been spent getting data, building metrics and doing statistics. He realised he had what he needed to build a service that would provide the metrics that were typically part of major academic articles, run them against the data and make them available to any PhD who wanted them.

This service would be very valuable to industry partners because it would enable anyone, including PhD students, to study market design changes in any market of the world in a matter of minutes. For example, US securities markets recently undertook one of the most important market design changes ever contemplated. The Securities and Exchange Commission (the US securities regulator) has promised an interim report within 18 months, yet the Market Quality Dashboard can provide these results on a 5-day rolling basis.

In his lifelong process of solving one problem after another, and building on the opportunities afforded by the solutions, Aitken has solved the problem he encountered 25 years ago when he first went to the securities marketplace. "It only took me 25 years, but what a lot of fun I had on the way!" he says.

To ensure it wasn't a fluke, he's applying his technology and know-how to other markets such as health and mortgages – two markets as fragmented as financial markets. He says there are billions of dollars of potential savings in health expenditure in Australia that can be used to bring significant improvements to consumers' health.

Aitken has now spun-off a separate entity, Lorica Health, which is using software-based surveillance to detect fraud, abuse, waste and errors in Australia's mammoth and fragmented health sector. Early indications are that there are savings worth billions of dollars per year that could then be directed to areas of service that would deliver huge health dividends to the country. "One of the more important opportunities here relates to the efficacy of health intervention itself," he says. "This requires an evidence-driven approach to identifying which treatments

About Michael Aitken

Michael Aitken is among the top 1000 authors publishing financial articles over the past 50 years. He is also a successful entrepreneur who founded both the Capital Markets Cooperative Research Centre and its predecessor, the Securities Industry Research Centre of Asia Pacific (www.sirca.org.au); the Reuters Tick History Service, which provides tick data to the world's academic and financial markets communities; and the SMARTS Group, a private Australian company that set the standard in real-time security market surveillance and was sold to NASDAQ-OMX in 2010.

Aitken has led the development of technology in the detection of fraud in the health and general insurance markets (www.cmc-is.com), and established an expert witness business providing specialist services for legal cases involving insider trading, market manipulation and continuous disclosure breaches.

In recognition of his contributions to business and academia in 1999 he was awarded the Business and Higher Education Roundtable Award for Outstanding Achievement in Collaboration in Education and Training. In 2010 he was named Ernst and Young ICT Entrepreneur of the Year, as well as NSW and Prime Minister Exporter of the Year.

In recognition of his significant service to the education, business and finance sectors of the nation, he was inducted as a member of the Order of Australia in 2014. He received the Prime Minister's Prize for Innovation in 2016.

deliver improved quality of life to patients, and which don't. So here we are looking at maybe \$20 billion per year that could be directed to improve healthcare in areas of genuine want."

Looking at everything that was created step by step, it's an ecosystem of companies that provide 200 permanent jobs and contribute \$6 million in tax revenues each year. Using funds from the sale of SMARTS to NASDAQ in 2010, Aitken and his teams have now invested in mortgage markets (www.dealmax.com.au), the café and restaurant supply chain marketplace (www.ordermentum.com), the building management market place (www.cimenviro.com) and the digital exchange and currency marketplace (www.digi.cash). Their ultimate goal is to fully replace government funding and secure a powerhouse of 100 permanently PhD students (and associated infrastructure) who will underpin innovation in Australia for decades to come.

This is a reinvention of academia as Aitken convinces his peers to come out of their ivory towers and plunge right into the microstructure of markets. They should not fear: the calibre of the research is such that academics associated with the CMCRC have published 122 articles in the top 12 journals in the field over the past 5 years, a major achievement for finance researchers.

Ann Leduc is the Head of Regulatory Practice at the Capital Markets Cooperative Research Centre.



Hiding in plain sight. The newly described *Oedura liritja*, a relict lizard from the Central Uplands, was long confused with another species. Credit: Peter McDonald

Something New, but Old, from Australia's Dead Heart

PAUL OLIVER & PETER McDONALD

The identification of an ancient gecko species discovered hiding in Central Australia has provided new insights into how and when Australia's deserts began to form 10 million years ago.

"Soon after leaving his camp I had the gratification to discover a magnificent specimen of the fan palm growing in the channel of the watercourse, with the drift of floods washed against its stem; its dome-shaped frondage contrasting strangely with the paler green foliage of the gum trees that surrounded it. It was a perfectly new botanical feature to me, nor did I expect to have met it in this latitude." — Ernest Giles, 30 August 1872

As someone familiar with the vegetation of the flat, dry and hot Australian deserts, the explorer Giles was surprised to discover a valley full of palms in the ranges of Central Australia. The nearest palms occurred hundreds of kilometres to the north, separated by vast expanses of unsuitable dry desert country.

Subsequent researchers have found dozens of similarly isolated species and populations of plants, snails, fish and other vertebrates in the ranges of Central Australia – "the Central Uplands". Most are separated from their nearest relatives by hundreds or even thousands of kilometres.

How and when did these plants and animals become localised?

One idea is that, just at the Central Uplands have provided a critical refuge for animals and Aboriginal people during droughts, they have also provided a refuge from the great aridification of Australia over far longer timescales. While more

than 70% of the island continent is a vast and climatically harsh arid zone, this has not always been the case. Palaeoclimatic data and fossils tell us that Australia has been progressively drying out over the past 10 million years.

This has had profound consequences for the plants and animals of Australia. Some adapted to the new environments, while others probably contracted to wetter areas along Australia's coast or else died out completely.

Like the coastal areas, could the Central Uplands have also provided climatically buffered refugia from the extremes of this aridification? This is a logical hypothesis from the data.

The Central Uplands include the highest mountains west of the Great Dividing Range (to 1531 metres), and there are isolated populations of cooler climate plant species that only occur on their summits. Likewise, nearby deep gorges provide cool refugia and permanent water, and are home to localised populations of water-dependent species such as fish and frogs – and of course, palms!

Palm Valley in Finke Gorge National Park. The palms in the foreground are not an ancient relict; they were most likely brought into Central Australia by people. However, living in the rocks behind was a true relict that had been overlooked. Credit: Catherine Nano

Based on this, many scientists had a further idea: perhaps by estimating the time of separation between Central Uplands isolates and their nearest relatives elsewhere in Australia, it would be possible to understand when current deserts spread across central Australia. Do they date back to initial aridification, potentially as long as 10 million years ago, or are they linked to much more recent intensifications of aridity through the glacials of the past few hundred thousand years?

It's only in the past couple of decades that we have gained the genetic tools that allow us to address these questions using information about levels of genetic divergence.

Surprisingly, a number of recent studies provide evidence that species endemic to the Central Uplands were not particularly divergent from their relatives found elsewhere in Australia, and certainly much younger than any estimate for the age of the deserts. Most remarkably, the iconic *Livistona* palms that Giles came across are actually the same as species occurring in northern Australia, and were probably transported by Aboriginal people. This is a fascinating story in itself, but also somewhat disappointing to the proponents of the ancient relicts story.

But what about other groups? Lizards in particular are a spectacularly successful group in Australia's deserts. There are many endemic species in the Central Uplands, including several that have only been recognised in the past decade. Among the lizards of these ranges there was one, noticed decades ago, that cried out for further investigation.

The story of this lizard began with, Robert "Bob" Bustard, a Scotsman who had a remarkable career including work in documentary-making, ecology, conservation and commercialisation of wildlife. However, his research all began with work on gecko ecology at The Australian National University, where he first noticed marbled velvet geckos in the sandstones around Kings Canyon that did not quite "look right" – they had colour pattern and scale differences to other velvet geckos found elsewhere in Central Australia.

However, for 40 years this is where things lay. In the absence of fresh genetic material, we were unable to test how divergent Bustard's velvet geckos really were.

Then, in 2014, Peter contacted Paul for an update on the taxonomic status of Central Australian lizards. The conversation turned to: "Are there any lizards from around Alice Springs that need further work?" Soon we had some tissues from Kings Canyon to finally understand how divergent the "funny velvet gecko" might be.

To our excitement it was most certainly not the same as the marbled velvet gecko, but instead a completely new, relatively



Spot the differences. On top is the newly recognised *Oedura luritja*, while at the bottom is *Oedura cincta*, another distantly related species that lives nearby with which it was long confused.

Credit: Peter McDonald



Nearly 30 isolated species or populations of vertebrates are only found in Australia's Central Uplands, including many that have only been described recently and others that are endangered. Ongoing genetic analyses will help us to understand when and how the spread of the vast Australian deserts isolated these relicts. Clockwise from top left: central tree frog *Litoria gilleni*; knob-tailed gecko *Nephrurus amyae*; dusky grasswren *Amytornis purnelli*; and the critically endangered central rock rat *Zyzomys pedunculatus*. Credit: Peter McDonald

large and quite colourful species that lives in some of the most visited parks in Central Australia. Peter was surprised to learn that the first velvet gecko he ever caught was, unknown to him at the time, a completely new species.

Even more exciting, further analyses of the genetic data suggest that it doesn't appear to have any close relatives (at least in comparison to all other described velvet geckos). We estimated that it diverged around 10 million years ago – similar to the timeframe other researchers have generated for when Australia may have first been undergoing major aridification. Based on this we think our new species might be a relict from these first aridification events.

In consultation with local Indigenous rangers we decided to name the new species *Oedura luritja* (although their first suggestion was to name it after a footballer!). This is a reference to both the Luritja people on whose land it occurs, and also related to the Arrernte word “Ulereny” meaning “stranger” – which seemed appropriate for such a deeply divergent lineage.

Our work is also showing that *Oedura luritja* is not alone. A number of other localised lizard species are showing evidence of similar deep splits from their nearest living relatives. We think this is underpinned by the rocks they live on.

The new velvet gecko in particular is specialised for a life on rock and has a flattened body that enables it to squeeze into crevices. The rocks themselves are hundreds of millions of years

old and may have provided a stable habitat with deep and climatically buffered crevices.

As Australia initially dried out in the late Miocene about 10 million years ago, relatives – which probably lived on trees in the surrounding plains – died out or moved somewhere else (once the trees were gone there was basically nowhere for them to live). However, *O. luritja* and some other lizards that it shares its habitat with have been able to hang on in the rocks for millions of years. So while the Central Uplands may have lost an ancient palm, they appear to have gained a suite of ancient lizards.

But the work is only just beginning. We have not yet carried out proper genetic analyses to understand the history and diversity of the vast majority of species that live in this special area.

Perhaps the most important question to ask pertains to the future. Are these isolated relicts extremely vulnerable to future climatic change, or are they well buffered from extremes in their rocky refugia? At the moment we simply don't have the answers to these questions.

More work seems certain to shed further light on how and when deserts spread across Australia, provide a better window into the conservation needs of these relict species, and no doubt result in a few more surprises!

Paul Oliver is a Postdoctoral Research Fellow in the Research School of Biology at The Australian National University. Peter McDonald is a government ecologist based in Alice Springs who is also completing a PhD in The University of Sydney's School of Biological Sciences.



It Pays to Grow Trees

VICTORIA GRAHAM

The deforestation of a peat swamp forest for palm oil production in Indonesia.

Credit: Aidenviroment/CC BY-SA 2.0

When economic forces threaten irreplaceable ecosystems in developing countries it makes sense to employ economic incentives that place a value on forests.

Four thousand kilometres from Darwin, a tropical jungle survives nestled precariously between vast urban and agricultural expanse. The Gunung Leuser National Park in Indonesia is the last place where all four critically endangered animals – Sumatran tigers, rhinos, elephants and orang-utans – still exist.

I was fortunate enough to see this jungle in 2016 and witness a majesty that is worth saving. In 2013 the government of Aceh province put forward a development plan that slices through the heart of the supposedly protected Leuser Ecosystem – one of the most irreplaceable ecosystems in the world – which would fragment the forests and may push critically endangered species like tigers and rhinos to extinction. Conservationists responded with fervour, attracting the support of celebrities such as Leonardo DiCaprio to campaign for its protection.

While this story is shocking, it's just one example of a much larger problem facing South-East Asia. Every year, 1.5 million hectares of forest are lost, much of it logged, burnt and replaced by agricultural, oil palm and timber estates, as well as infrastructure, in attempts to stimulate regional economic growth.

The protection of these forests is of international interest for social and environmental reasons, yet the value of forests like these remains largely unrecognised. Until this changes, this ignorance will cost us greatly.

Protecting Wild Nature

The history of formal forest protection dates back to 1872 when Yellowstone National Park became the world's first official national park. More and more areas of natural significance have since been reserved for conservation, in recognition of their recreational and environmental value. In theory, protected areas aim to provide safe havens for biodiversity and are regulated by laws that are actively enforced.

Indonesian parks are home to many of the world's quirkiest and most appealing species, drawing tourists from far and wide to glimpse animals of prehistoric appearance, such as the Komodo Dragon or our closest living relatives, the orang-utan. Let's not forget weird and wonderful plants such as the titan arum, otherwise known as the "corpse flower" for its rotting stench. Travelling into these parks is often a saddening experience as visitors can witness pristine habitats being destroyed or see first-hand evidence that poachers are actively hunting nearby.

During 2010 in nearby Vietnam, the Javan rhinoceros met a tragic end when the last known wild rhino was found dead with a single bullet in its leg and its horn removed. This butchering occurred in the Cat Tien National Park, which the World Wildlife Fund (WWF) had described as the "last refuge for a lost animal". In 2011 the WWF announced that the species is officially extinct in Vietnam. In Indonesia, "save the rhino" campaigns are striving to protect the last 100 Sumatran rhinos



The Sumatran orang-utan (*Pongo abelii*) is critically endangered due to habitat conversion and illegal hunting. Credit: Victoria Graham

surviving in the wild, in an attempt to avoid the same plight of extinction.

This tragic story of illegal wildlife exploitation is unfortunately not an isolated one. But of greater concern is the mass land-clearing taking place throughout South-East Asia to support regional plans for agricultural and urban expansion. In the process, forests are being decimated and the wildlife they support is becoming threatened or even driven to extinction. The process typically starts with new roads being built. Once operational, roads provide new access to forests that are often rich in timber but were previously too remote to reach by loggers, farmers and settlers.

A recurring obstacle to ending the relentless conversion and degradation of natural habitats is money. Economic pressure drives the conversion of natural habitats in several ways. First, national plans to boost economic growth drive forest loss as additional land is cleared to increase output from agriculture and other sectors. An example is the oil palm boom in Borneo and Sumatra. In another way, poverty drives resource exploitation as communities living in and around forests often rely on

forest products to survive. In developing countries like Indonesia and Vietnam there is a third pattern at play: inadequate financial support for forest conservation.

Several studies have demonstrated a severe underfunding of protected areas in South-East Asia, and found that this links with illegal forest exploitation due to weak law enforcement. Scientists have long warned us that ineffective law enforcement and poor management of protected areas will place insurmountable pressure on nature refuges to protect threatened species, ultimately driving some to extinction. However, for tropical developing nations like Indonesia, the finance required to change this is within reach.

There's Money in Trees

In 2005 an initiative was proposed by a group of 15 countries led by Papua New Guinea and Costa Rica. This Coalition for Rainforest Nations would campaign for a market-funded mechanism to slow deforestation in tropical developing countries.

The proposal led to the REDD+ scheme, which is focused on Reducing Emissions from Deforestation and forest Degradation, plus conserving and sustainably managing forests and enhancing forest carbon stocks. REDD+ aims to provide the economic incentives needed to conserve forests by linking financial payments with carbon stored in trees (from either reducing forest-based emissions or enhancing forest carbon stocks). The goal of the United Nations-backed initiative is to lower carbon emissions in developing countries by paying to keep forests alive and standing, or by planting more forests.

The momentous support the scheme has attracted since its inception is largely due to the way it recognises the financial value of the carbon storage and sequestration function of healthy tropical forests. After all, tropical forests hold around half of the carbon stored in forests worldwide, and their destruction contributed to ~15% of anthropogenic carbon emissions between 1990 and 2010. REDD+ has already attracted more than US\$7.3 billion from countries including Norway and Australia, marking a serious investment in climate mitigation.

In a recent article in *Environmental Research Letters* my colleagues and I drew attention to the financial and carbon gains of projects that reduce forest-based emissions in South-East Asia through REDD+. Our study found that financing improved management of protected areas, which reduces emissions from illegal deforestation and supports biodiversity conservation, was highly cost-effective. On average US\$13 could reduce 1 tonne of carbon emissions. The new finance contributed to hiring additional park staff, infrastructure, education and training programs to prevent illegal logging and agricultural encroachment.

Another cost-effective opportunity for REDD+ was removing carbon from the atmosphere through tropical refor-

A large oil palm plantation outside the Gunung Leuser National Park in Sumatra.
Credit: Victoria Graham



estation, costing on average US\$9 per tonne of carbon. Furthermore, the scope for reforestation is vast, with millions of hectares of degraded land in Indonesia currently sitting idle. Reforesting this total area could achieve a carbon gain of 965 million tonnes of carbon over 30 years. The fact that these cost-effective opportunities for lowering forest carbon emissions even exist is extremely promising and must be better recognised.



The oil from the palm fruit is valued for its use in food products, cosmetics and as a biofuel. Credit: Victoria Graham

An important distinction of REDD+ is that it does not aim to hinder development plans, but to implement cost-effective and sustainable mitigation activities that promote the long-term, healthy management of forests, carefully planning how to use land so that forests like the Leuser Ecosystem aren't destroyed. For example, REDD+ promotes the sustainable harvesting of timber in existing logging concessions, as timber provides vital income for local communities. However, the carbon benefit comes from enforcing sustainable logging techniques, such as pre-harvest vine cutting and directional felling to reduce wastage and residual damage during log-harvesting.

The objective of REDD+ is to balance a nation's need for development with the daily and future needs of its people. This means planning for development and economic growth while also considering the long-term provision of natural resources. If resources run dry, it can bring poverty to a devastating number of people.

It was this problem that motivated my colleagues and I to draw attention to cost-effective climate mitigation activities and see how REDD+ finance can be harnessed to protect valuable ecosystems like Leuser. Natural systems provide vital benefits to society, including clean drinking water, climate regulation and erosion control. These are currently largely undervalued.

Our research aimed to find out which strategies were most commonly employed by REDD+ projects in South-East Asia, and see how they compare in terms of costs and carbon gains. To do this, we collected information on the location and threats

being targeting at each REDD+ project site in South-East Asia. Some examples of threats included the conversion of natural forests to oil palm, timber and other crops, and illegal deforestation inside parks.

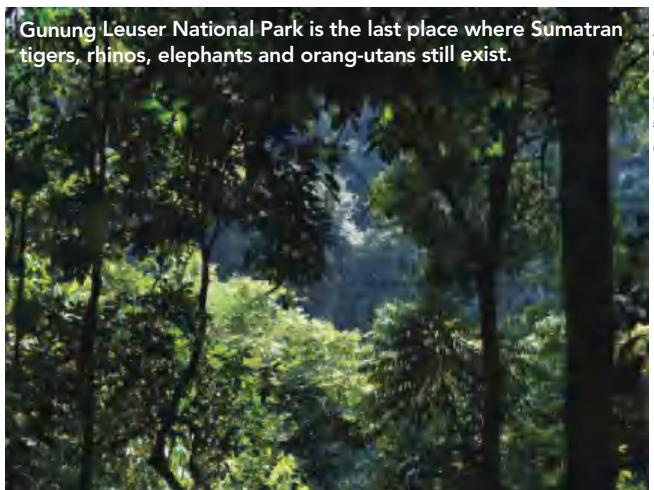
There could be several threats at each site that require different REDD+ strategies to address them. For example, the REDD+ strategy employed at a project site threatened by oil palm expansion was to buy the land and prevent the forest from being cleared and replaced by oil palm. We estimated the costs and carbon gains of each strategy by reviewing the literature.

Our research led to a few key findings. First, Indonesia was the clear regional leader in REDD+, with ~70% of projects located in Indonesia alone, predominantly on the islands of Borneo and Sumatra, which are the two islands that experienced the highest forest loss for 2000–2010. Second, more than 60% of projects were aimed at improving the management of protected areas and reforesting tropical forests, which were also the cheapest strategies. Conversely, less projects were using funds to purchase land that was planned for oil palm and timber plantations, which were the most expensive strategies.

The key take-home message of this is that cost-efficient opportunities for reducing emissions and conserving forests in South-East Asia exist and are already being tapped into, but activities could be further expanded with additional support from donor countries in recognition of the multitude of benefits attainable for both developing and developed countries.

In summary, realising the value of tropical forests will foster a healthy long-term relationship between people and forests that has huge benefits for all. Natural systems provide vital benefits to society, including clean drinking water, climate regulation and erosion control. These are currently largely undervalued. The lesson for us all is to not lose sight of the value of tropical forests or the difficulties that developing countries face in protecting them. After all, investing in forests may be the smartest investment we ever make.

Victoria Graham is a Masters candidate at James Cook University.



Gunung Leuser National Park is the last place where Sumatran tigers, rhinos, elephants and orang-utans still exist.

Roads to Ruin

Can we build roads that benefit people while not destroying nature?

We are living in the most aggressive era of road-building in human history. The International Energy Agency projects that by 2050 we will have another 25 million kilometres of paved roads on Earth – enough to encircle the globe more than 600 times. Nine-tenths of these roads will be built in developing nations, mostly in the tropics and subtropics, which sustain the planet's most biologically rich and environmentally important ecosystems.

This modern road-building spree is terrifying ecologists like us, because we know that new roads often open a Pandora's box of environmental ills – exposing vulnerable ecosystems to an influx of human colonists, hunters, miners and land speculators. In the Amazon, for instance, our research shows that 95% of all deforestation occurs within 5.5 km of a legal or illegal road. In Africa, roads bulldozed by loggers are crisscrossing the Congo Basin, allowing waves of poachers armed with modern rifles and snares to penetrate deep into forests. In just the last decade, two-thirds of Africa's forest elephants have been slaughtered for their valuable ivory tusks.

Almost everywhere we look we see roads causing one environmental crisis after another. The same things are happening on Australia's northern doorstep in Indonesia, Malaysia and Papua New Guinea. All three of these nations have ambitious plans to open up their last frontier areas to exploit timber, construct new mines and hydropower dams, and expand



Some 95% of all deforestation in the Amazon occurs within 5.5 km of a road, while for every kilometre of legal road there are nearly 3 km of illegal roads.

Credit: Google Earth

farming. Can they achieve this while not destroying their remarkable biodiversity or sacrificing their forests and the critical services they play in regulating our climate, limiting destructive floods and sustaining indigenous peoples?

That is the great challenge our research team at James Cook University is attempting to confront. We are working with dozens of decision-makers, scientists and conservationists in the Asia-Pacific to devise strategies to promote human welfare while simultaneously saving some of the most critical vestiges of nature.

The Benefits of Roads

Despite their potentially severe environmental impacts, economists will tell you that we need roads. These are an indispensable part of our modern societies, providing a cost-effective way to promote economic growth, encourage regional trade and provide access to natural resources and land suitable for agriculture. They also have more dubious political uses, such as shoring-up the claims of nations to disputed geopolitical boundaries.

One of the most pressing reasons to build new roads is to increase agricultural production and food security. The tropics currently have 40% of the world's population and 55% of its young children (under the age of five). By 2050 it's expected that more than half the world's population and two-thirds of its young children will reside there. Nearly all tropical nations will see major increases in population size, with global food demand expected to double as a result.

Given these realities, our goal is to encourage road building in places that will maximise food production. Agriculture in many developing nations performs far more poorly than it could because farmers lack access to affordable fertilisers, modern crop varieties and farming methods, as well as urban markets where their crops will bring the highest prices. With



Roads don't just bring poachers: shown here is a road-killed Malayan tapir in Peninsular Malaysia. © WWF-Malaysia/Lau Ching Fong

better roads in lands that have already been largely settled by farmers, there is enormous potential to improve farming – doubling or even tripling the amount of food produced on each hectare of arable land.

Improving roads in already-settled areas can bring further benefits. It will encourage more rural investment and give local residents better access to health care and schools. As farming in such areas becomes more profitable, they can also begin to act as “magnets” that attract colonists away from forested frontiers. In this way, better roads can amp up farming in settled areas while helping to spare shrinking wilderness areas for nature conservation.

Avoiding the First Cut

While part of our research focuses on where to locate and improve roads to benefit people, we are also concerned with benefiting nature. One lesson we have learned is that deforestation behaves very much like a cancer. Across the world, forest clearing is highly “contagious” spatially, as new clearings tend to spread out from existing clearings.

So when someone cuts the first road into a pristine forest, deforestation begins to grow along the road, much like how cancerous tumours will grow. The road then spawns secondary and tertiary roads, and the cancer seeds and spreads. The key lesson is that there is no such thing as having a little bit of cancer. If you have a bit of cancer you’ll soon have a lot more cancer. The best solution is to avoid getting cancer in the first place.

For forest conservation, then, the message is to avoid the first cut. Don’t put roads into places you want to conserve, at least not unless you’re willing to bear the long-term costs of monitoring those roads and stopping forest colonisation and deforestation. A second key lesson is to, wherever possible, close existing roads in high-risk places such as prime wilderness, much as you would surgically cut out a cancer before it grows and spreads.

Turning Theory into Action

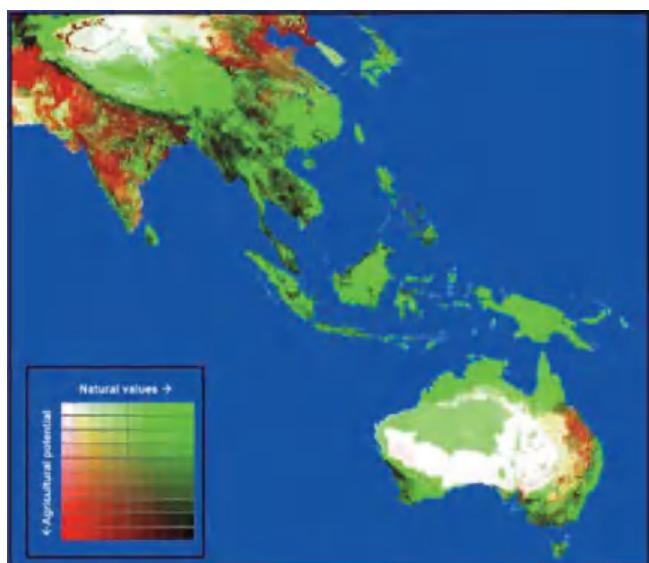
These ideas sound simple in theory, but in practice it gets more complicated. We use field observations, satellite data, mapped datasets and sophisticated computer models to generate our road-prioritisation schemes. Our very first model, published in *Nature*, was highly ambitious: we devised a road-mapping scheme for the Earth’s entire land surface.

However, global-scale datasets are too coarse for road planning at national and regional scales, so now we are focusing on a series of environmentally critical regions. We’re beginning with northern Sumatra in Indonesia: the very last place on Earth where orang-utans, tigers, elephants and rhinos still survive together. After that we will be moving to Indonesian



Credit: William Laurance

For farmers in already-settled lands, such as this woman growing cassava in the Solomon Islands, new or improved roads can increase farm production and improve rural livelihoods.



From Laurance et al. 2014. A global strategy for road building. *Nature* 513:229–232.

Our first attempt at a strategy for prioritising road building in the Asia-Pacific region. Green areas in this image have high environmental values and relatively low agricultural potential; red areas have high agricultural potential and lower environmental values; and black areas are “conflict” zones where environmental and agricultural values are both high.

Papua, and after that probably to Borneo. There is no shortage of urgent places to work; in fact, we could increase the size of our team by tenfold and we’d still be flat-out trying to develop road-mapping schemes for ecosystems under urgent threat.

The bottom line is that we desperately need to plan infrastructure, especially proliferating roads, much better than we’re doing at present. If we don’t, we are going to see many of the Earth’s last wild places vanishing before our eyes.

A famous Brazilian scientist once said: “The best thing you could do for the Amazon is to blow up all the roads”. He was probably right, but in the real world that just isn’t an option. We have to learn to live with roads, and do everything we can to ensure that nature can live with them as well.

Mason Campbell and Mohammed Alamgir are postdoctoral research fellows working under lead researcher William Laurance at James Cook University’s Centre for Tropical Environmental and Sustainability Studies.

Personality Influenced by Brain Structure

Individual differences in personality have been associated with structural variation in the cortex.

Individual differences in patterns of thinking, feeling and behaving are what makes each of us unique, and the variety of personality types has long been a field of study for psychologists. While traits have traditionally been measured using questionnaires and observations of behaviour, it may soon be possible to assess an individual's personality through examination of patterns of brain structure and function. In a recent study, researchers have found associations between personality traits and structural aspects of the brain, such as the thickness, size of surface area and degree of folding of specific regions of the cortex.

The history of psychology is littered with theories of personality, ranging from the quasi-astrological to the rigorously scientific. From his therapeutic analysis of neurotic Viennese, Sigmund Freud proposed that human behaviour reflects the interaction of three unconscious structures: the id, ego and superego. Later approaches developed theories from statistical analyses of people's responses to lists of words or statements.

"... it provides hope that further research will identify biological markers for personality disorders or other behavioural, emotional or cognitive problems..."

In the 1950s, Hans Eysenck concluded that personality comprised three main factors that he termed extraversion–introversion, neuroticism–stable and psychotism. In contrast, Raymond Cattell argued that three dimensions were insufficient to conceptualise the diversity of personality, and he developed a 16-factor model. Gordon Allport went even further, combing a dictionary for personality-related adjectives to argue that more than 4000 traits could be discriminated.

Since the 1990s, modern personality theory has been dominated by the "five-factor model". Derived from factor analyses of questionnaires completed by very large samples, these "big five" dimensions are labelled Neuroticism (moodiness and emotional instability), Extraversion (sociability, enthusiasm and expressiveness), Openness (imagination, creativity and open-mindedness), Agreeableness (prosocial behaviour, trust and empathy) and Conscientiousness (thoughtfulness and goal-directed behaviour). Cross-cultural studies have shown that these five factors are present in people from diverse backgrounds, with longitudinal studies demonstrating that these dimensions

are relatively stable through the adult years.

Like earlier personality theories, the five-factor model assumes that traits have developed as a result of an interaction between innate, biologically determined dispositions and environmental variables, especially parenting and other early experiences. Family and twin studies have suggested that these personality traits are largely heritable but are also affected by experience. However, evidence of associations between personality dimensions and biological markers has remained elusive, with correlations between specific traits and brain structure or function found only occasionally and inconsistently.

In the recent study published in *Social Cognitive and Affective Neuroscience*, a team of Italian, American and British researchers speculated that prior research has been constrained by samples either of small size or significant heterogeneity, and by limitations in the methods of quantifying the size of specific brain regions. To address these methodological problems, they engaged 507 healthy young adults to complete the NEO Five-Factor Inventory, a 60-item questionnaire designed to assess the "big five" personality traits, and to undergo a brain scan that enabled the measurement of variability in cortical thickness, surface area, cortical volume and folding.

Analyses revealed strong associations between each of the five personality domains and the brain measurements, especially in the frontal regions of the brain. As had been previously shown in other studies, the thickness of a region of the cortex was inversely related to the size of its surface area and degree of folding: put simply, as a part of the cortex develops it either grows thicker or folds over upon itself.

However, the present study added the new finding that this structural variability is correlated with personality dimensions. To take the two strongest associations, high Neuroticism was associated with a thicker cortex in prefrontal–temporal regions and thus a smaller surface area and less folding, while Openness was related to a thinner cortex in prefrontal–parietal regions, with greater surface area and increased cortical folding.

While the study replication, its demonstration of associations between these personality dimensions and specific anatomical variables supports the validity of the five-factor personality theory. More importantly, it provides hope that further research will identify biological markers for personality disorders or other behavioural, emotional or cognitive problems, opening the possibility of early diagnosis and targeted therapeutic intervention.

A/Prof Tim Hannan is Head of the School of Psychology at Charles Sturt University, and the Past President of the Australian Psychological Society.

Getting a Palaeontology Job in Australia

Australia's funding system disadvantages students attempting to turn their palaeontology studies into a career.

In September 2015 this column looked at how school students interested in fossils can get into a degree and formally study palaeontology. But how does one get a real job and secure a career in the fossil business?

It's certainly not easy, but neither is it impossible. Each year we see a good number of students apply to study palaeontology at universities around Australia. This year Flinders University is offering its first major in vertebrate palaeontology, the branch that offers sexy research topics on fish, mammals, dinosaurs and other backboned critters. This begs the question: how does a student get that first foot onto the career elevator?

The first step is getting a postdoctoral position. The Distinguished Early Career Researcher Awards (DECRA) given out by the Australian Research Council (ARC) are very hard to win. In the most recent round only 17% of applicants were successful. Usually only researchers applying in their fourth or fifth years after their postgraduate degree win them, simply because they need a few years as an active researcher to rack up the necessary publications to be competitive. That's the catch.

The only other way is for the student to excel at their research and get offered a postdoc by their supervisor. They need to publish some highly significant papers. To do this the student must be given a really good research project that ensures that high quality outcomes are possible.

If their supervisor is successful with their own ARC grants they can build in a postdoctoral salary for the student to begin their career, perhaps providing the 3-year start necessary to publish and be competitive to win a DECRA. However, most of the ARC Discovery Grants are cut by around 40%, so the ability to find funds to support a 3-year postdoc is now getting increasingly harder.

Another factor makes it very difficult for our own home-grown palaeontology postgraduates to compete in this market. Our students are currently given 3 years funding, with a possible 6-month extension, to complete their PhD. Compare this to some students from overseas who have completed a Masters degree and then do a 5–6 year PhD. They naturally have more publications notched up after spending 8 or more years as a postgraduate. They therefore have a much more competitive track record than most Australian students with just 3–4 years research experience.

The DECRA system is open to students from around the world to compete, as long as a university here is willing to support them. The DECRA should be a level playing field, but in reality it simply isn't, and our students are the ones who lose out.



Dr Brian Choo recently received a DECRA for palaeontological research at Flinders University.

"The DECRA should be a level playing field, but in reality it simply isn't, and our students are the ones who lose out."

A young palaeontology postdoc has few career options. There are jobs in a museum (e.g. curator, collection manager) or as a university lecturer. Both of these careers are not full-time research positions as they involve a block of time spent either teaching or doing exhibition and public relations work. Palaeontologists can also include administration in their career path and end up doing high-level management as a senior museum executive or university administrator.

The trade-off at this level is that one's time for research diminishes as one goes higher up the administrative ladder. Currently the CEO of the one of largest natural history museums in the USA, The Smithsonian, is Dr Kirk Johnson, a palaeontologist. He's in a dream job, but he had to work very hard to get there.

To succeed in palaeontology one must work very hard, and be just a bit lucky that a position arises at the right time and place. Good luck with it all.

John Long is Strategic Professor in Palaeontology at Flinders University, and current President of the Society of Vertebrate Paleontology.

Changing the Way We Do Things

We need to have a critical mass of women in key roles.

As we seek to increase gender diversity and create more opportunities for talented women, we need to be aware that we are looking to change the way things are done, which can be uncomfortable.

We want to create a better society for Australians, and that means we have to draw on all the talent that is available, both men and women, but be respectful and consider others' views as we seek to bring about change. We will have a better society when we fully draw on the talent of all of our people.

We also need to recognise where there has been success, and that's reflected in the increasing number of women on boards and the surge among younger women choosing to study engineering. Leadership has been the key in both cases.

The proportion of women board members in the ASX200 is now at 25%, compared with just 8% back in 2008, which was when there was a wake-up call that something needed to be done as the representation of women actually went backwards.

"... organisations that pride themselves on being a meritocracy can be at greater risk of their judgements and actions being biased."

The 30% Club, supported by the Australian Institute of Company Directors, targets 30% of the ASX200 board members being women by 2018. The appointment rate of women to ASX200 boards was running at 40% in 2016 – the run rate required to achieve the 2018 target.

In the engineering area there is strong leadership evident. At The University of Queensland, 22.9% of its undergraduate engineering students were female in 2016 – well above the 2015 national average of 17%. The University targets 30% female participation in its undergraduate engineering programs by 2023.

The University of NSW has reported that it offered a record number of engineering places to female students this year. One in four engineering offers went to female school-leavers. UNSW Engineering targets 30% by the end of the decade.

It is terrific to see the progress being made on the board front, but the much greater challenge is increasing the number of women in the most senior executive roles as these have the most influence and decision-making power in organisations. We need more women in roles such as Chief Executive Officer (CEO), Chief Financial Officer (CFO) and heads of business units.

In late 2016 I became President of Chief Executive Women (CEW), which represents more than 400 of Australia's most senior women from the corporate, public, academic and not-for-profit sectors. The organisation's mission is "women leaders enabling women leaders".

As CEW's President, I have set myself the goal of having an impact on the rate of appointment of women to the most senior executive roles in organisations, and not just appointment to senior support roles. Everyone in organisations knows which roles are the most important. We need to have a critical mass of women in them.

Once again the key is going to be leadership. Although there are no silver bullets, we know what is required. Leaders must be able to communicate a compelling case for change, to build a top team with gender diversity, to play a strong role in key recruitment and promotion decisions, to set challenging targets, and to act as a sponsor for talented women and men.

Often a discussion around sponsorship leads to a question of whether it is consistent with concepts of merit and meritocracy. The answer is that merit should be the basis for appointments, but sponsorship can help ensure that the right people are considered.

It is also important to recognise that great care needs to be taken when looking at "merit". Last year, CEW along with the Male Champions of Change released a report on avoiding the "merit trap", because organisations that pride themselves on being a meritocracy can be at greater risk of their judgements and actions being biased. In particular, it is critical to look at both performance and potential when considering candidates for appointment. We also need to be careful to avoid defining "merit" as "people like us".

One of the challenges for organisations is to look beyond individual merit and consider institutional merit. One of my favourite quotes on the topic comes from Lieutenant General Angus Campbell, Chief of Army, who reflects on the difference between individual merit and institutional merit:

Institutional merit is not the same as individual merit. If you choose a senior executive team based only on individual merit, you get a monologue. Institutional merit creates a strong diverse Army, not a strong list of individuals.

Focusing on institutional merit is a key to the quest for greater diversity.

Kathryn Fagg FTSE is a Director of the Reserve Bank of Australia and ASX-listed companies Boral, Djerrirwarrah Investments and Incitec Pivot. She chairs the Academy's Industry and Innovation Forum.

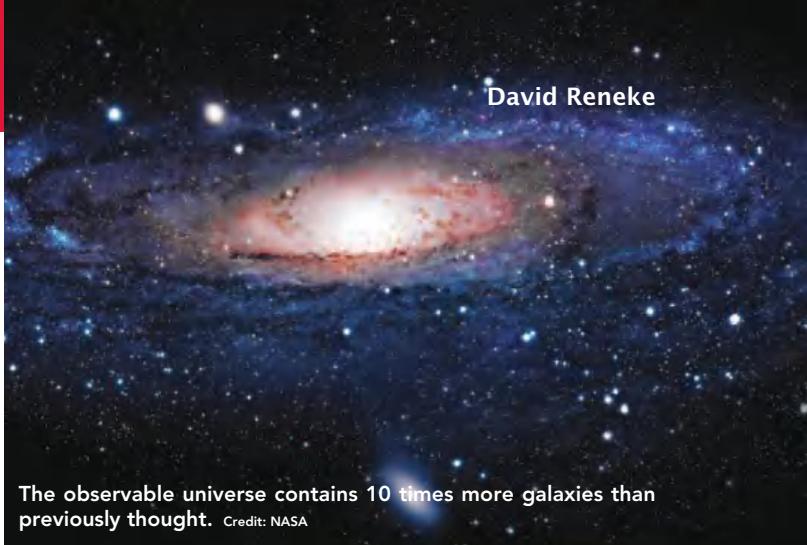
Census Finds Universe Has Ten Times More Galaxies

Astronomers using data from the NASA/ESA Hubble Space Telescope and other telescopes have performed an accurate census of the number of galaxies in the universe, and concluded that there are at least 10 times as many galaxies in the observable universe as previously thought. The results have clear implications for our understanding of galaxy formation, and also help solve an ancient astronomical paradox – why is the sky dark at night?

One of the most fundamental questions in astronomy is how many galaxies the universe contains. The Hubble Deep Field images, captured in the mid-1990s, gave the first real insight into this. Myriad faint galaxies were revealed, and it was estimated that the observable universe contains 100–200 billion galaxies.

Now, an international team led by Christopher Conselice of the University of Nottingham has painstakingly converted the Hubble images into 3D in order to make accurate measurements of the number of galaxies at different times in the universe's history. In addition, they used new mathematical models that allowed them to infer the existence of galaxies that the current generation of telescopes cannot observe.

This led to the surprising realisation that in order for the



The observable universe contains 10 times more galaxies than previously thought. Credit: NASA

numbers to add up, some 90% of the galaxies in the observable universe are actually too faint and far away to be seen right now.

In analysing the data, the team looked more than 13 billion years into the past. This showed them that galaxies are not evenly distributed throughout the universe's history. It's powerful evidence also that a significant evolution has taken place in which galaxies merged together, dramatically reducing their total number.

The decrease over time also contributes to the solution of Olbers' paradox – why the sky is dark at night. The team concluded that every point in the sky contains part of a galaxy, but most are invisible to the human eye and even to modern telescopes.

A combination of factors like red-shifting of light and its absorption by intergalactic dust and gas all combine to ensure that the night sky remains mostly dark.

David Renike is an astronomy lecturer and teacher, a feature writer for major Australian newspapers and magazines, and a science correspondent for ABC and commercial radio. Subscribe to David's free Astro-Space newsletter at www.davidreneke.com

When Two Moons Collide

The Moon, and the question of how it was formed, has long been a source of fascination and wonder. Now a team of Israeli researchers have suggested that the Moon we see every night is not Earth's first moon, but rather the last in a series of moons that orbited the Earth in the past.

The newly proposed theory runs counter to the commonly held "giant impact" scenario that the Moon is a single object that was formed following a single giant collision between a small Mars-like planet and the ancient Earth.

"Our model suggests that the ancient Earth once hosted a series of moons, each one formed from a different collision with the proto-Earth," said Prof Hagai Perets of the Technion and Weizmann Institute in Israel. "It's likely that such moonlets were later ejected, or collided with the Earth or with each other to form bigger moons." To check the conditions for the formation of such mini-moons or moonlets, the researchers ran 800 simulations of impacts with the Earth.

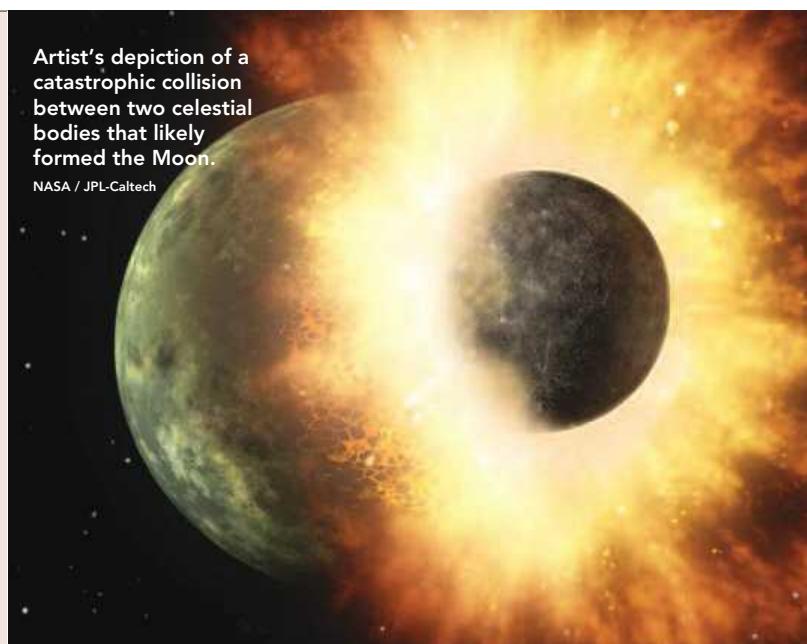
The new model is consistent with science's current understanding of the formation of the Earth. In its last stages of growth, Earth experienced many giant impacts with other bodies. Each of these impacts contributed more material to the proto-Earth until it reached its current size.

"We believe the Earth had many previous moons," said Perets, who added that "a previously formed moon could therefore already exist when another moon-forming giant impact occurs".

The tidal forces from the Earth could cause moons to slowly migrate outwards. The current Moon is slowly doing that at about 1 cm/year.

Artist's depiction of a catastrophic collision between two celestial bodies that likely formed the Moon.

NASA / JPL-Caltech



A pre-existing moon would slowly move out by the time another moon forms. However, their mutual gravitational attraction would eventually cause the moons to affect each other and change their orbits.

"It's likely that small moons formed through the process could cross orbits, collide and merge," said Perets. "A long series of such moon-moon collisions could gradually build up a bigger moon, which of course is the Moon we see today."

Protecting Your Health in a Post-Truth World

As scientific literacy declines and “post-truth” and “alternative facts” take centre stage, how can you ensure that you get proper health treatments that will actually do some good?

“Post-truth” is a term coined in 2010 to describe a political culture in which appeals to emotion defeat factual evidence in debate. It has now gone mainstream, selected in 2016 by *The Oxford English Dictionary* as the word of the year. One year later, “alternative fact” entered the lexicon as US President Donald Trump’s advisers fabricated stories about his inauguration that were easily falsified by well-documented and even photographic evidence.

These terms came from politics, but could well have come decades ago from science as climate change, genetically modified organisms, nanotechnology, alternative energy and other scientific and technological advances produced barrages of hostile and falsifiable criticism that was readily shown to be untrue by huge amounts of consistent, published and replicated data. To this day such rebuttal, relying on factual evidence rather than heightened emotion, proves remarkably ineffective in shaping public attitudes.

Nowhere is this more evident than in what now masquerades as the health industry, with discredited “wellness warriors”, anti-vaccination proponents, revolutionary diets, mystical healers and miracle fruits flooding the electronic media daily.

Why? Explanations vary, but “confirmation bias” is central; the tendency to seek out, prefer, believe and remember information that fits with one’s pre-existing beliefs while discounting evidence that does not.

Journalists know that someone watching, reading or hearing their story has an invisible thought bubble above their head saying: “How does this affect me or the people I love?” As with politics and religion, health is a fertile emotional field to seed with alternative facts and post-truths.

It is made worse by the internet, but perhaps in unexpected ways. The internet was hailed as a creation that would revolutionise and assist both education and communication, and it can,

but everything that technology produces is a two-edged sword; whatever is powerful can be powerfully good or equally powerfully bad. The internet gives us untold opportunities for education, communication and news but also unrivalled opportunities for pornography, terrorism and cyberbullying. Now add fraudulent health treatments.

The public is very much at risk here. The Australian Institute of Health and Welfare maintains that 59% of Australians aged 15–74 lack the health literacy skills adequate to access health services and manage their health effectively.

Doctors and pharmacists were the traditional authorities to whom patients turned for advice. Increasingly it is the internet, complete with hucksters, self-appointed gurus, unethical marketers and proponents of completely untested and even impossible cures. Worse, some doctors and pharmacists are joining them, with pharmacists promoting products such as homeopathic preparations and useless vitamin supplements and some doctors embracing dubious alternative practices as “integrative medicine”. Financial viability is the usual excuse.

In the clamour of online claims from celebrity actors, chefs or sporting champions, expecting those with poor health literacy to understand the relevance of evidence-based treatments, derived from well-run clinical trials reported in refereed journals of high quality, is getting much harder in this post-truth world.

You might expect professional and governmental bodies will protect consumers against false health claims. They exist, but can be remarkably weak. Most are under-resourced, while others rely on self-accreditation that is easily flouted. Some will explore complaints but take months or years to do so, with few or any penalties imposed, while various supervisory boards have a predominance of the very practitioners they are supposed to police, and vested interest renders them useless.

Of course, climate change, genetically modified organisms, nanotechnology, alternative energy and orthodox medicine have all produced their own errors, and even frauds. They get wide media coverage, but we know of these because the time-proven scientific method, with its onus on publication, encourages challenges to and replication of results. This makes it possible to detect unlikely findings and reveal them as the scientific “post-truths” and “alternative facts” that they are.

It is an imperfect system, but it is far superior to accepting at face value the self descriptions and non-validated claims of those who want your dollar in return for the treatment of their own devising. No such checks and balances apply there.

Dr Rob Morrison is a Professorial Fellow at Flinders University and Vice-President of Friends of Science in Medicine.



Don't Let Straw Men Give You Hay Fever

Be prepared to face these straw man arguments when arguing with climate change deniers, anti-vaccination advocates and creationists.

In my previous column I talked about the futility of using straw man arguments in debates. A straw man is a statement that intentionally misrepresents your opponent's belief or position. I also said that the use of such arguments is usually due to ignorance, and advised that it is wise to actually research your opponent's position before going into battle if you don't want to look foolish.

However, some discussions will almost certainly result in the appearance of a straw man argument, and part of your research into your opponent's position is to predict such usages and be prepared for them. If you are not prepared, a straw man, like a non sequitur, can divert the conversation, waste your time and make you, the recipient, look foolish, unprepared and maybe even dishonest.

There is an internet tradition that dates back to the days when Usenet was the most popular forum for discussion, yet it still applies in the Facebook era. It is Godwin's Law, and in its original form was: "As any Usenet thread gets longer, the probability that Hitler or the Nazis will be mentioned gets greater".

There needs to be a new such law stating that in discussions with certain types of people, the probability that a straw man argument will surface increases with time. Here are a few examples of inevitable straw men that will appear if you attempt to debate certain people.

Climate change deniers have three they regularly use. The first is attempting to confuse weather with climate. Where I live, the weather right now is hot and dry. Six months ago it was almost constantly raining; in 4 months the roads will be closed by snow (but not as often or with as much snow as 30 years ago). That's weather. Climate is weather events smoothed over time – the grapes in the vineyards now ripen a few weeks earlier than they did a decade or so ago. Before the recent rain (the heaviest for 50 years, and at a different time of the year than farmers remember) the local dam was at its lowest for a very long time. The climate is changing, and one piece of evidence for this is increased variability of the weather.

Another straw man, which really should be called "cherry picking", is to point to a series of years that show a decreasing average temperature. This is a dishonest use of statistics, and the sort of thing I was warned about in my first statistics course at university.

The third straw man is to refer to and discredit research done by the Intergovernmental Panel on Climate Change. To quote from the IPCC's web site: "It does not conduct any research nor does it monitor climate-related data or parameters". But the deniers know that.

Vaccine opponents also call on several straw men. One is that vaccines are "injected directly into the bloodstream," bypassing the body's natural protective barrier. No vaccines are injected into the bloodstream, but having to explain this can take up valuable time.

Another is to claim that vaccines are not tested for safety. I once responded to this claim by linking to a list of several thousand scientific papers, only to be asked if I had read all of them myself and if I could confidently state that they weren't all the same single study constantly repeated. (Sometimes you just have to give up. I did.) They will often say: "You claim that all vaccines are 100% effective and absolutely safe". No we don't, but time can be wasted pointing this out.

"... some discussions will almost certainly result in the appearance of a straw man argument, and part of your research into your opponent's position is to predict such usages and be prepared for them."

The one that is always a lie because they know the truth is that vaccines contain "mercury". No childhood vaccine has contained the preservative thimerosal since 2000, and it is almost non-existent now. But the deniers know that.

There is also the regular claim from vaccine deniers and supporters of alternative "medicine" that the American Medical Association (and the Australian Medical Association) controls the manufacture and distribution of vaccines and drugs. The AMAs (both of them) are non-compulsory doctors' trade unions, and might have input into government policy decisions but don't make or enforce the rules.

The final group of regular straw man users is the creationists. They use too many to list here, but the best is probably: "Evolution can't explain the origin of life". That isn't its job – evolution explains how we got here from there. In one debate I tried to squash this by saying that "God did it," but I was told that as an atheist I wasn't allowed to say that.

We have to resist using straw man arguments ourselves, but we always have to expect that some will come over the net towards us. Be like the boy scouts, and "be prepared".

Peter Bowditch is a former President of Australian Skeptics Inc. (www.skeptics.com.au).

The Feasibility of a Cane Toad Barrier

Preventing the spread of cane toads into Western Australia's Pilbara could cost less than \$100,000 per year.

Cane toads are one of Australia's worst invasive species. Over the past 85 years they have spread across more than 1 million km² of northern Australia. Along the way, the toads have had severe impacts on native biodiversity, such as goannas and quolls.

The toads seem unstoppable, but new research suggests there may be a chink in their seemingly impenetrable armour. The toad's weakness, it seems, is its inability to retain water.

Cane toads lose water at the same rate as a sponge; they need access to water every 3–4 days or else they dehydrate and die. As the toads have penetrated further into arid regions of Australia, they have increasingly relied on artificial water sources – such as pastoral dams and tanks – to rehydrate and breed. It makes sense, then, that we might be able to stop the toad invasion in arid areas by preventing toads from accessing these water points. But where might we apply such a strategy?

It turns out that a thin "corridor" of pastoral land between Broome and Port Hedland, in Western Australia, is the perfect trap. Here the Great Sandy Desert almost reaches the coast. The cane toads will really have to squeeze through this narrow bottleneck to reach the Pilbara and continue spreading through Western Australia.

A previous study, using computer simulations, suggested that replacing about 100 pastoral dams and tanks with leak-proof tank and trough systems along this stretch of coastline just might do the trick. A number of non-government organisations and local management groups expressed interest in the waterless barrier idea, but others had reservations.

Why the doubt? Were they concerned with the data and assumptions underpinning the simulation? Or did they just misunderstand its limitations and capabilities?

To find out, we decided to ask them. To do that, we ran a workshop in Broome with local practitioners and experts in cane toad biology – the people with intimate knowledge of the landscape and of the invader. Attendees revealed that they were most concerned about the accuracy of input data going into the model, such as rainfall variability and the locations of dams, and other land uses in the corridor that might support toad populations.

In response to those concerns, we updated our previous simulation to incorporate this information. We drove the entire length of the corridor, verifying the locations of artificial and

natural waterbodies on every property between Broome and Port Hedland. We also mapped a variety of other points that could potentially provide refuges for toads, such as dwellings, homesteads and roadhouses, as well as regions of irrigation and cropping. Our work enabled us to produce the most up-to-date map of permanent water and land use on pastoral land between Broome and Port Hedland.

With these updated maps, we then investigated the most cost-effective location for a waterless barrier in the corridor. This involved simulating the spread of toads through the region in the absence of waterbody management, and then testing barriers placed at 17 potential locations. An economic model estimating the upfront installation and ongoing maintenance costs of a barrier was developed to find the most cost-effective barrier location. The updated model was run with and without local knowledge of the landscape to determine if this information affected the best barrier location.

The results of the analysis suggest that the toad invasion front could be contained by excluding toads from fewer than 100 waterbodies, at a cost of approximately \$4.5 million over 50 years. That's less than \$100,000 per year.

This is considerably less than the amount spent on other invasive species management programs in Australia. For example, the Australian government recently spent \$19 million on feral camels in Central Australia over 4 years, and \$35 million on the fox eradication program in Tasmania over 8 years.

Importantly, our research demonstrates the importance of engaging practitioners during model development. Local knowledge overlooked in the original incarnation of the model – specifically, knowledge about irrigation and dwellings – influenced the best location for a barrier.

Our new research suggests that the idea of a waterless barrier to halt the spread of cane toads is both feasible and cost-effective.* It is also a win-win situation for pastoralists and conservationists, as the installation of leak-proof tanks could improve farm productivity while simultaneously mitigating a key threatening process for biodiversity.



Since the cane toad has difficulty retaining water, its remorseless march across Australia might be stopped if we can build a waterless barrier. Credit: Reid Tingley

Darren Southwell and Reid Tingley are members of the ARC Centre of Excellence for Environmental Decisions (CEED). They are based at the University of Melbourne.

*If you are interested in this strategy, Ben Phillips discusses how the waterless barrier can be made even more effective in the September 2016 issue of *Australasian Science*.

Yes, Science Minister

The merry-go-round of science ministers raises concerns about instability.

Australia has a new science minister, the fourth in the past 18 months. The Academy of Science's secretary for science policy, Prof Les Field, noted: "This is the kind of instability that would typically raise a red flag, especially for a sector like science where training, work programs, infrastructure requirements and outcomes all have timeframes much longer than election cycles".

Some of us remember golden ages of stability, such as when Barry Jones was minister for more than 7 years or Kim Carr for more than 4 years. In the British TV program *Yes, Minister*, the wily bureaucrat Sir Humphrey Appleby said that reshuffles kept ministers "on the hop" and avoided the danger of politicians knowing enough about their portfolio to challenge the advice they received. That was certainly true of Barry Jones.

Arthur Sinodinos comes to the portfolio with a chequered past, marked by his inability to recall questionable financial dealings when called before the NSW Independent Commission Against Corruption. But he does have a reputation for being an effective political operator. The science community will be hoping to see that in action.

Sinodinos' recent predecessors have laid some important groundwork. In December 2015, Christopher Pyne announced the National Science and Innovation Agenda. This promised 10 years of funding for the National Collaborative Research Infrastructure Scheme. That program has funded 27 projects in a wide range of scientific fields including nanotechnology, astronomy and genetics.

Greg Hunt took over the role of science minister after the 2016 election in July. During his short period in the office, Hunt pledged to support the innovation agenda and increase public sector research spending, as well as saying he

hoped to increase private sector spending on innovation.

A critical indicator of progress will be the National Research Infrastructure Roadmap, which is due to be finalised in the next few months. Canberra-watchers have expressed concern that the current government plans to reduce its budget problems by raiding the Education Investment Fund, which was established by the ALP government 9 years ago to support research infrastructure.

It will be an early test of Sinodinos as the new minister to see whether he is able to obtain the funding needed for science and commercial innovation.

It made headlines recently when the "Doomsday Clock" was shifted to a new setting of two-and-a-half minutes to midnight, the nearest the clock has been to midnight for more than 50 years. The Science and Security Board of the Bulletin of Atomic Scientists said that "the probability of global catastrophe is very high, and the actions needed to reduce the risks of disaster must be taken very soon".

Ten years ago, the Bulletin added climate change to its historic focus on the threat of nuclear weapons. It should be an urgent warning to world leaders.

As if to reinforce the message, we are seeing more disturbing reports about the impacts of climate change. US scientists have been monitoring the huge Zachariae Isstrom glacier in Greenland. It began to melt rapidly in 2012 and is now crumbling into the Atlantic Ocean, losing ice at a staggering rate of 4.5 billion tonnes per year. The researchers believe that the glacier will continue retreating at a rate of more than 1 km/year until it reaches a ridge about 30 km inland.

A neighbouring large glacier is also melting rapidly. The two contain enough



Senator Arthur Sinodinos is the fourth science minister in 18 months.

ice to raise global sea levels by about 1 metre.

Closer to home, Australian researchers have shown that five uninhabited islands in the Solomons have disappeared as a result of rising sea levels. They were all small, low-lying islands, ranging in size from one to five hectares.

More significantly, on two other islands in the archipelago whole villages have been destroyed and people forced to relocate. Worst hit was the island Nuatambu, reported to have lost half its habitable area and 11 houses. Several of the displaced people have moved to a nearby volcanic island that is higher above sea level. On another island, Nararo, affected villagers have been able to retreat inland to higher ground.

The collaborative study by scientists from four Australian universities concluded that this was hard evidence of the impacts of sea level rise, rather than inappropriate development.

Ian Lowe is Emeritus Professor of science, technology and society at Griffith University.

Locked-in's Challenge to Autonomy

Four patients with locked-in syndrome have communicated that they are happy as long as they receive adequate care at home.

The craze for Marvel superheroes encourages us to think that merely being human is too easy. We need to exceed our limitations by adding superpowers – breathing underwater, eternal youth, colossal strength, regeneration, flying, spinning spider webs and so on. Of course, that's just comic book stuff, but the same dynamic is at work in the Olympic goal of going "faster, higher, stronger".

It's a facet of the homage we pay to "autonomy", the key value of contemporary bioethics. If our autonomy is diminished, we are diminished as human beings. Our happiness is deemed to be proportionate to our autonomy.



A brain-computer interface enabled communication with patients in the completely locked-in state. Wyss Center (www.wysscenter.ch)

But medicine offers the competing narrative that less might sometimes be more.

Nothing illustrates this better than that rare condition, locked-in syndrome (LIS). Most people first learned of it after reading the international bestseller *The Diving Bell and the Butterfly*, or watching the film of the same name.

Jean-Dominique Bauby, the editor of the French edition of *Elle*, suffered a massive brain stem stroke while driving. When he woke up he was completely paralysed, apart from the upper eyelid of his left eye. Yet within 2 years he had written his book, which exudes a remarkable *joie de vivre*. He composed it by blinking when an assistant said a letter. Even in translation his prose was dazzling:

[M]y mind takes flight like a butterfly. There is so much to do. You can wander off in space or in time, set out for Tierra del Fuego or for King Midas's court. You can visit the woman you love, slide down beside her and stroke her still-sleeping face. You can build castles in Spain, steal the Golden Fleece, discover Atlantis, realize your childhood dreams and adult ambitions.

And Bauby's condition, terrible as it may seem, is not the worst way of experiencing LIS. He seems to have had "classic LIS" and retained some eye movement. Other patients retain some voluntary movement. But then there is "total LIS" in which the patient is immobile, fully conscious and unable to communicate.

Until now, perhaps. A paper published recently in *PLOS Biology* by Swiss scientists describes a computer interface that can decipher their thoughts. Four patients with total LIS were able to respond "yes" or "no" merely by thinking the answers. A non-invasive brain–computer interface detected their responses by measuring changes in blood oxygen levels in the brain.

Here is the interesting part. Contrary to expectations, the question "Are you happy?" resulted in a consistent "yes" response from the four patients. The lead author, Prof Niels Birbaumer of the Wyss Center, added:

We were initially surprised at the positive responses when we questioned the four completely locked-in patients about their quality of life. All four had accepted artificial ventilation in order to sustain their life, when breathing became impossible; thus, in a sense, they had already chosen to live. What we observed was that as long as they received satisfactory care at home, they found their quality of life acceptable.

This study marks a big step forward in communicating with people with LIS, but it is not the first to report that such patients are satisfied with life. A 2003 study in the *Journal of Head Trauma Rehabilitation* about Americans with LIS found that half were happy and half were occasionally depressed. The authors commented: "Clinicians may not appreciate that quality of life often equates with social, rather than physical interaction, and that the will to live is strong".

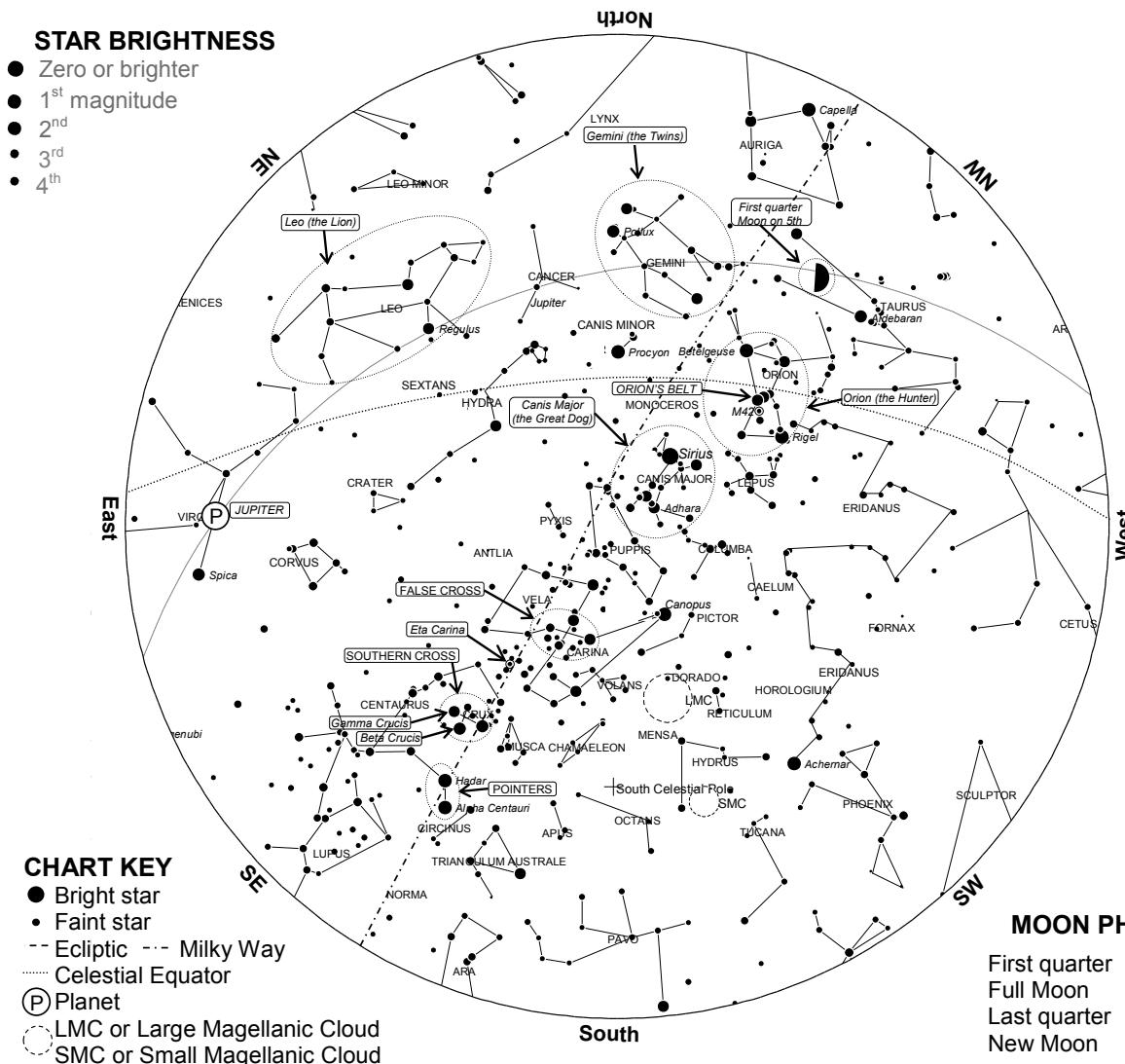
Clearly, it is possible for people to reach deep within themselves and find happiness even with the most severe disability imaginable – if they are supported by family and friends. What is important is not to project our own fear of total disability onto the patient. As the authors of the American study wrote:

[We] call into question the assumption among some health care providers and policy makers that severe disability is intolerable. This prejudice is not inconsequential. Biased clinicians provide less aggressive medical treatment and/or influence family and friends (in ways not appropriate to the situation).

In a sense, the experience of LIS patients raises important questions about autonomy. What if we don't need autonomy to be happy? What if all we need is love?

Michael Cook is editor of BioEdge, an online bioethics newsletter.

March 2017



THE CHART

The star chart shows the stars and constellations visible in the night sky for Sydney, Melbourne, Canberra, Hobart and Adelaide for March at about 8.30pm (Daylight Savings Time) and at about 9.30 pm (Local Standard Time) for Perth and Brisbane. For Darwin and similar locations the chart will still apply, but some stars will be lost off the southern edge while extra stars will be visible to the north. Stars down to a brightness or magnitude limit of 4.5 are shown on the star chart. To use this star chart, rotate the chart so that the direction you are facing (north, south, east or west) is shown at the bottom. The centre of the chart represents the point directly above your head, called the zenith point, and the outer circular edge represents the horizon.

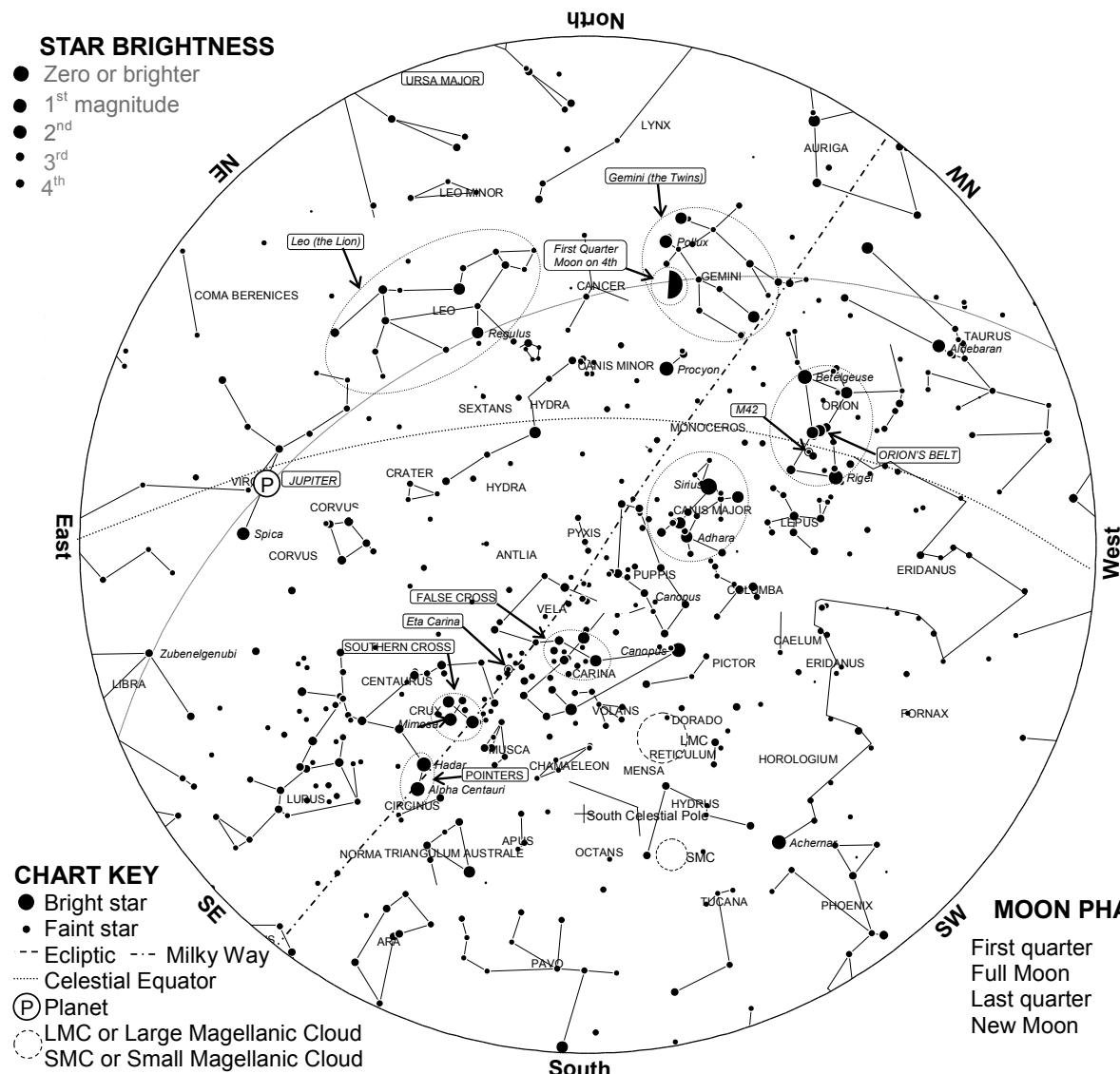
HIGHLIGHTS IN MARCH 2017

The best time to view the Moon with a small telescope or binoculars is a few days either side of the first quarter Moon on the 5th. You may catch a glimpse of Venus or Mars towards the west just after sunset. Jupiter, the largest planet in our solar system, can be found rising from the eastern horizon and will be visible throughout the night. In 2017, the Autumnal equinox falls on the 20th of March. Prominent in the sky this month, are the constellations of Canis Major (the Great Dog), Orion (the Hunter), Gemini (the Twins) and Leo (the Lion). Crux (the Southern Cross) is low in the south eastern sky.

Sydney Observatory is part of the Museum of Applied Arts and Sciences. The Sydney Observatory night sky map was created by Dr M. Anderson using TheSky software. This month's edition was prepared by Brendan Dew. © 2017 Museum of Applied Arts and Sciences, Sydney.



April 2017



THE CHART

The star chart shows the stars and constellations visible in the night sky for Sydney, Melbourne, Canberra, Hobart, Perth and Brisbane in April at about 8:00pm (local standard time). For Darwin and similar northerly locations the chart will still apply, but some stars will be lost off the southern edge while extra stars will be visible to the north. Stars down to a brightness or magnitude limit of 4.5 are shown on the star chart. To use this star chart, rotate the chart so that the direction you are facing (north, south, east or west) is shown at the bottom. The centre of the chart represents the point directly above your head, called the zenith point, and the outer circular edge represents the horizon.

HIGHLIGHTS IN APRIL 2017

The best time to view the Moon with a small telescope or binoculars is a few days either side of its First quarter phase on the 4th. The largest planet in our solar system, Jupiter, can be easily spotted within the constellation of Virgo (the Maiden) in the east. Prominent in the sky this month, are the constellations of Canis Major (the Great Dog), Orion (the Hunter), Gemini (the Twins) and Leo (the Lion). Crux (the Southern Cross) is low in the south eastern sky. Crux can be easily located as it is always adjacent to so-called Pointer stars of Centaurus (the Centaur).

Sydney Observatory is part of the Museum of Applied Arts and Sciences. The Sydney Observatory night sky map was created by Dr M. Anderson using the *TheSky* software. This month's edition was prepared by Brenan Dew. © 2017 Museum of Applied Arts and Sciences, Sydney.



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