ULTIMATE CAREERS

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Mathematicians rule the world, says young scientist Sophie Calabretto

FINDING SPACE

Future travel throughout the universe is creating exciting jobs here on Earth

A SPECIAL FEELING

THE WORLD OF GAMING AND VFX IS ON THE HUNT FOR COMMITTED NEW RECRUITS

INTRODUCTION

INSIDE THIS ISSUE

THE SCIENCE OF FINDING A CAREER

THE STUDY OF science is the study of life, and the most important character traits you need to make a success of the field are curiosity and persistence. Among the many scientists – be they mathematicians, technologists, engineers or any of a thousand other disciplines – telling their stories in these pages, the chief qualities they display are a driving curiosity to learn more about the world around them, and true grit when it comes to following their dreams.

Each one chose their field of study because some part of the natural or physical world spoke to them in a personal way – Dr James Waldie could not resist the idea of exploring space; the call of mummies from ancient Egyptian tombs was a siren song for Dr Ronika Power; Nick Mower as fascinated by video games and creating new worlds and stories for them. For others, it took a while to find their calling, but each clearly recognised their field of endeavour when they found it and pursued it relentlessly, even those whose academic skills were less than stellar.

Their message is, if you find a science career you love, go for it, and don't be afraid to combine fields from the sciences and the arts to achieve the best outcome.

Doing so is likely to lead to a satisfying job that will keep you setting off sparks until your retirement party.

You might even find a way to safely colonise Mars, save a threatened species or discover a cure for a debilitating disease.

These pages will show you how each curious, persistent individual we talked to has responded to their own challenges and their advice to those who follow in their wake. A life more interesting awaits.

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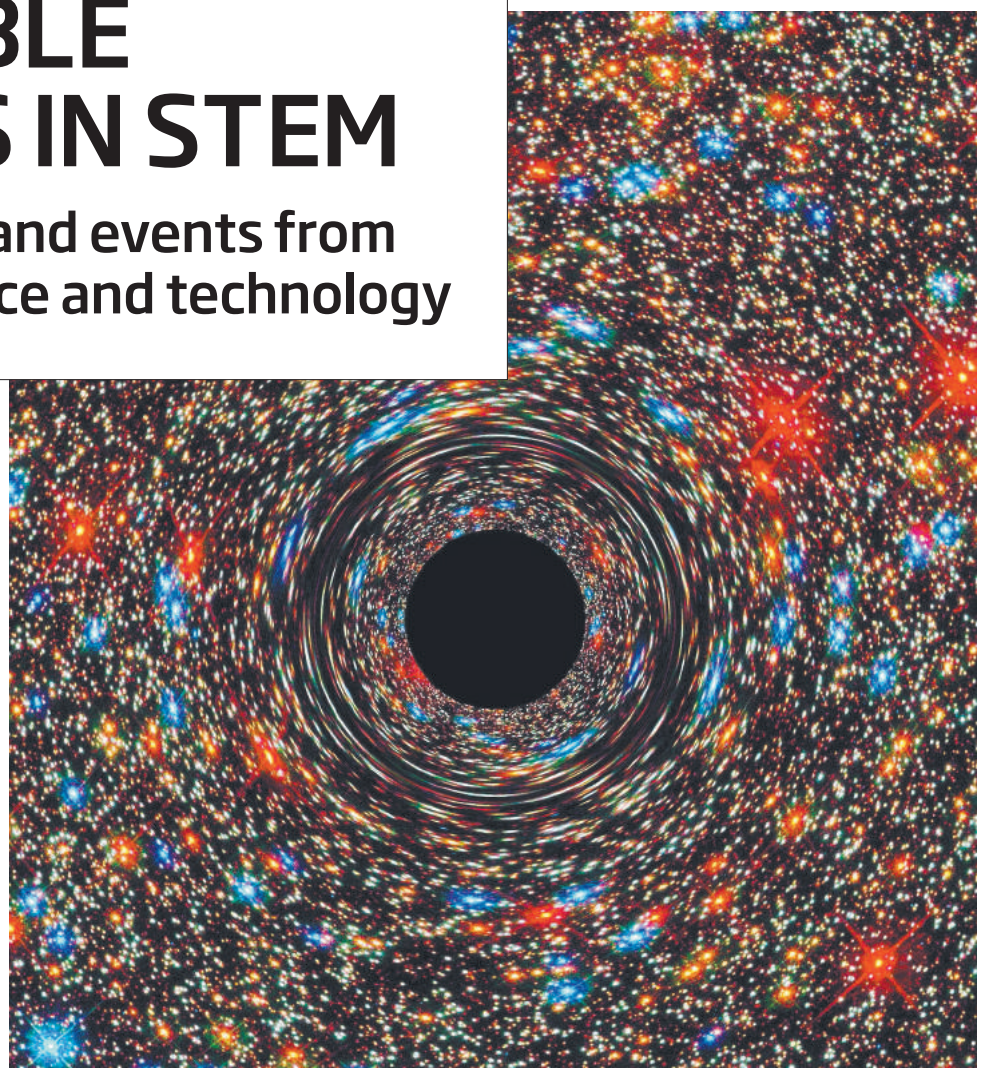
DEGREE AREAS

- **Science (Biology + Chemistry + Physics)**
- **Earth and Environmental Sciences**
- **Maths**
- **Engineering**
- **Computer Science**
- **Architecture**
- **Business**
- **Agriculture**
- **Medical**
- **Psychology**

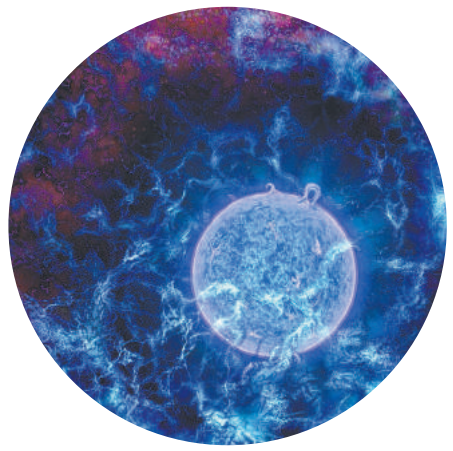
MEMORABLE MOMENTS IN STEM

Recent advances and events from the world of science and technology



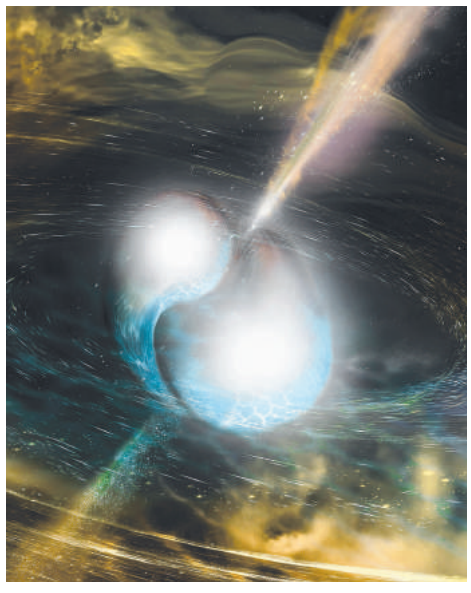
BLACK HOLE ILLUMINATES

Astronomers have discovered the fastest-growing object in the universe: a black hole that devours a mass equivalent to Earth's sun every two days. Scientists at the Australian National University's Research School of Astronomy and Astrophysics say the super-massive black hole is more than 12 billion light-years away in deep space and is about the size of 20 billion suns, expanding 1 per cent every one million years. Such giant and rapidly growing black holes are extremely rare. It was spotted by the European Space Agency's Gaia satellite and confirmed using a spectrograph at the ANU's Siding Spring Observatory in NSW.



BIRTH OF THE FIRST STARS

Faint signals from the "cosmic dawn", just 180 million years after the Big Bang, have been detected in the Australian Outback. At CSIRO's Murchison Radio-astronomy Observatory in WA, a simple antenna picked up the telltale sign of star birth. The Experiment to Detect the Global Epoch of Reionizaton Signature, known as EDGES, has been searching for 12 years. The signature was produced as the first stars reacted with hydrogen gas in the early Universe. "Because of their radiation exciting the intergalactic gas, we are able to see the cold shadow of hydrogen in the early Universe absorbing the background radio emission," says Swinburne University's Distinguished Professor Karl Glazebrook.



When Neutron Stars Collide

Astronomers witnessed "history unfolding" in front of their eyes as they focused their telescopes on a signal created when two ultra-dense neutron stars collided.

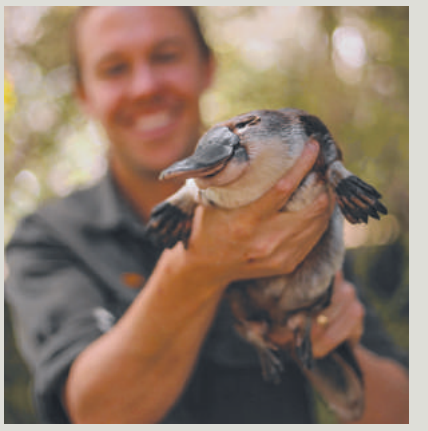
Shockwaves and light flashes emitted by the cosmic fireball travelled about 130 million light-years to be captured by Earth-based detectors last year.

The data finally revealed where much of the gold, platinum, mercury and other heavy elements in the Universe comes from. Telescopes saw evidence of newly forged material in the fallout – a source long suspected and now confirmed.

Neutron stars are the condensed, burnt-out cores that remain when massive stars run out of fuel, blow up and die. About 20km in diameter, with slightly more mass than our sun, they are highly radioactive and ultra-dense. Just a handful of material from a neutron star would weigh as much as Mount Everest, scientists say.

It had been theorised that mergers of two such exotic bodies would create ripples in the fabric of space-time, known as gravitational waves, as well as bright flashes of high-energy radiation called gamma ray bursts. Both phenomena were witnessed coming from the same spot in the constellation of Hydra.

The observation was the work of thousands of scientists at more than 70 ground and space-based observatories around the globe.



WONDER MILK

A breakthrough by Australian scientists has brought the introduction of an unlikely hero in the global fight against antibiotic resistance a step closer: the humble platypus. In 2010, scientists discovered that platypus milk contained unique antibacterial properties that could be used to fight superbugs.

This year, a team of researchers at CSIRO, working with Deakin University, has solved the puzzle of why platypus milk is so potent – bringing it one step closer to being used to save lives.

The discovery was made by replicating a special protein contained in platypus milk in a laboratory setting, then deciphering its structure to get a better look at it. What they found was a unique, never-before-seen 3D fold, which will help inform future drug-discovery work.

In 2014, the World Health Organisation released a report highlighting the scale of the global threat posed by antibiotic resistance, pleading for urgent action to avoid a "post-antibiotic era", where common infections and minor injuries, which have been treatable for decades, can once again kill.

> We will always have STEM with us. Some things will drop out of the public eye and some things will go away, but there will always be science, engineering and technology. And, importantly, there will always, always be mathematics.
>
> **KATHERINE JOHNSON, NASA MATHEMATICIAN**

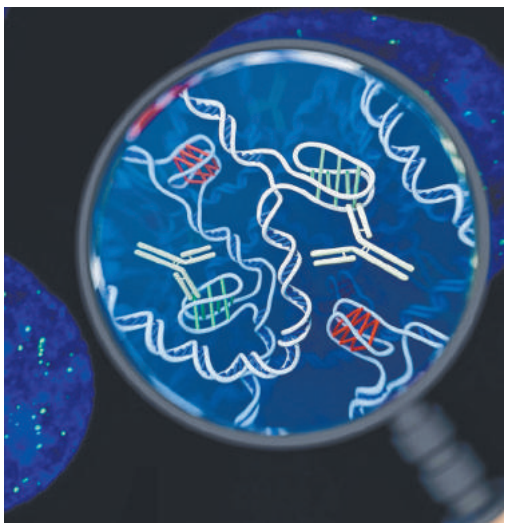
Plastic Pariah

Microplastics have become a major bogeyman this year, with environmentalists and scientists pointing out the extent of plastic pollution accumulating in our oceans, rivers and living creatures. The millions of tiny manufactured microbeads in body wash, scrubs and toothpaste are just one source of microplastics that end up in the ocean. Other culprits are fibres from synthetic fishing nets and clothes and the fragmentation of larger plastic objects, especially plastic bags, discarded into the environment. Scientists are finding microplastics almost everywhere they look for them in oceans and lakes, and their impact on marine life and our food chain is still being studied. Several countries have introduced or moved to introduce various forms of bans on microbeads, including New Zealand, the US, UK, Canada, Ireland, Taiwan and Sweden. The Australian Government is still considering its position.

REEF BLEACHED

Concern for corals on the Great Barrier Reef peaked in April with the release of research showing a die-off after the 2016 heatwave. The authors of the paper, published in the journal *Nature*, mapped the patterns of heat exposure and coral death along the 2300km length of the Reef after the extreme marine heatwave of 2016. They found many corals died immediately from heat stress, while others died more slowly as their algae partners (zooxanthellae) were released because of the heat. "The results ... confirm our worst fears of the detrimental impact man-made climate change is having on the Great Barrier Reef, and our natural ecosystems as a whole," says Dr Sarah Perkins-Kirkpatrick from the University of NSW.

New Form of DNA Found



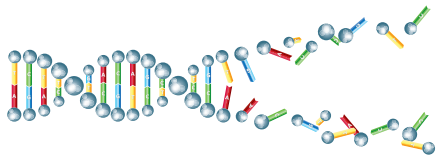
Scientists have identified a twisted knot of DNA, the i-motif, inside living cells. This new shape is a four-stranded knot of DNA. DNA is known for its iconic double helix shape but DNA is not bound to just one configuration. While DNA takes on its double helix form to efficiently store the genetic code, it also needs to adopt structural changes when that information needs to be accessed. They have previously known about and seen the existence of i-motifs but this is the first time scientists have witnessed it inside a living cell, and reminds us that totally different DNA structures exist and could well be important for our cells.

Look up at the stars and not down at your feet. Try to make sense of what you see, and wonder about what makes the universe exist. Be curious.

STEPHEN HAWKING

ALZHEIMER'S REPAIR

Scientists at Gladstone Institutes in San Francisco made a major breakthrough towards discovering a cure for Alzheimer's disease. The researchers extracted stem cells from Alzheimer's patients and healthy volunteers and used these cells to create neurons (brain cells). The Alzheimer's patients all had two copies of the apoE4 gene – which greatly increases one's risk of developing Alzheimer's. Scientists studied the neurons of both healthy individuals and those affected by Alzheimer's. By doing so, they discovered the apoE4 gene causes Alzheimer's via the increased production of a neuron-damaging protein. Once the researchers figured out the protein promoted Alzheimer's disease, they developed a method that allowed them to change its structure. By doing so, they erased any evidence of Alzheimer's in the damaged neurons and the cells became healthier and lived longer.



QUANTUM LEAP

A teleportation machine is here. Well, sort of. Scientists in China teleported properties of light particles called photons from the ground into outer space for the first time this year, using mirrors and lasers. It was a huge success for quantum physicists, who say the finding could completely change how we move energy and information around the world. The technique is more exciting for our screens than ourselves – it could lead to a new kind of quantum computing that would work in entirely new ways. This kind of super-speed quantum internet would be a safer, faster, virtually hack-proof kind of communication.

ROCKET MAN

Elon Musk's SpaceX conquered a major challenge for space travel in February by launching its monster rocket, the Falcon Heavy, on a historic test flight.

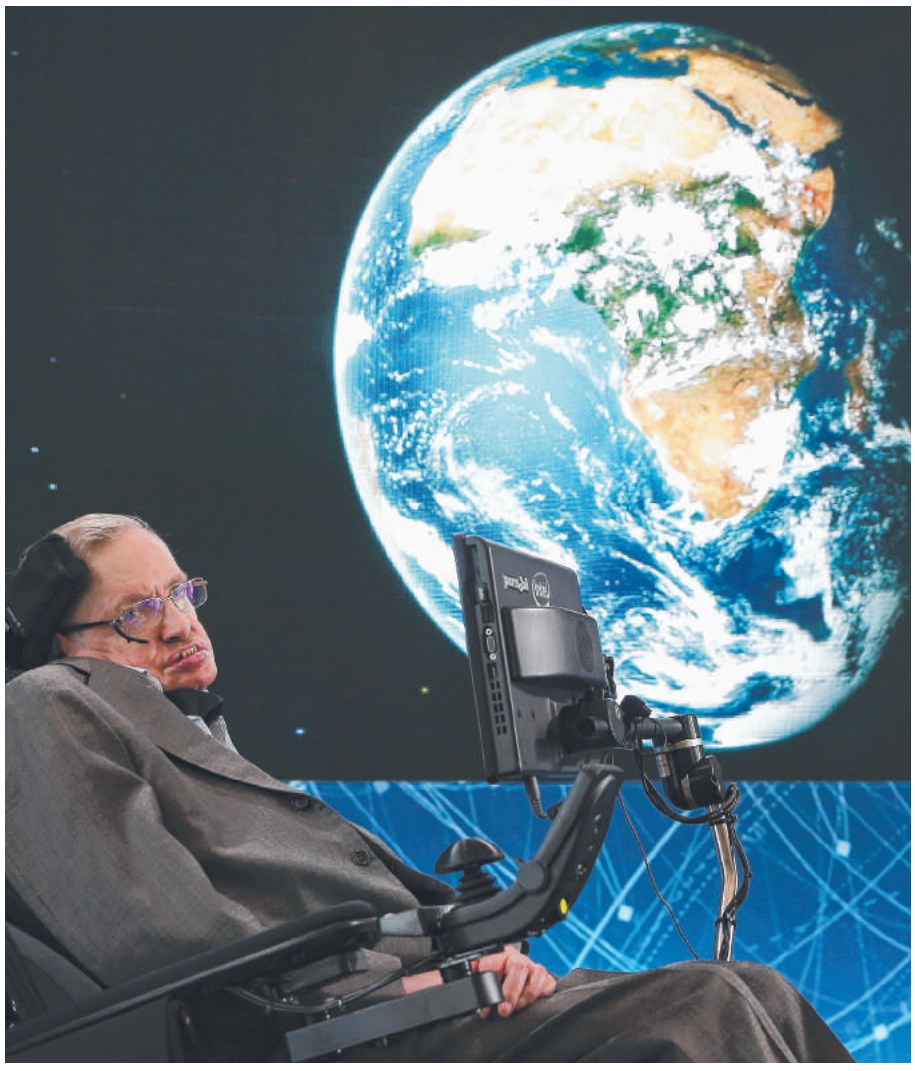
The rocket launched its payload – a Tesla roadster – on its journey to the edge of Mars before returning and landing back on Earth. Two of the boosters were recycled and also programmed to return for a simultaneous touchdown at the launch site, while the third, brand new, set its sights on an ocean platform off Florida.

The near-flawless launch and return show the way forward in terms of rocket power and reuseability to reduce the cost of space exploration.

The rocket is the most powerful in operation today and is designed to one day take supplies to the Moon or even Mars. The last time a rocket this powerful was launched was during the Apollo missions in the 1960s and '70s.

REMEMBERING STEPHEN HAWKING

The death of Stephen Hawking at age 76 was greeted with great sadness by the global scientific community. Hawking is largely responsible for the three laws of black hole dynamics that form the basis of our understanding of these objects. The detection of the gravitational waves in 2016 showed the world how these laws work in practice. Associate Professor Lisa Harvey-Smith from CSIRO highlighted that perhaps his greatest legacy was his idea that, like aspirin in a glass of water, black holes slowly dissolve over time, leaking a type of radiation that now bears his name: Hawking radiation.

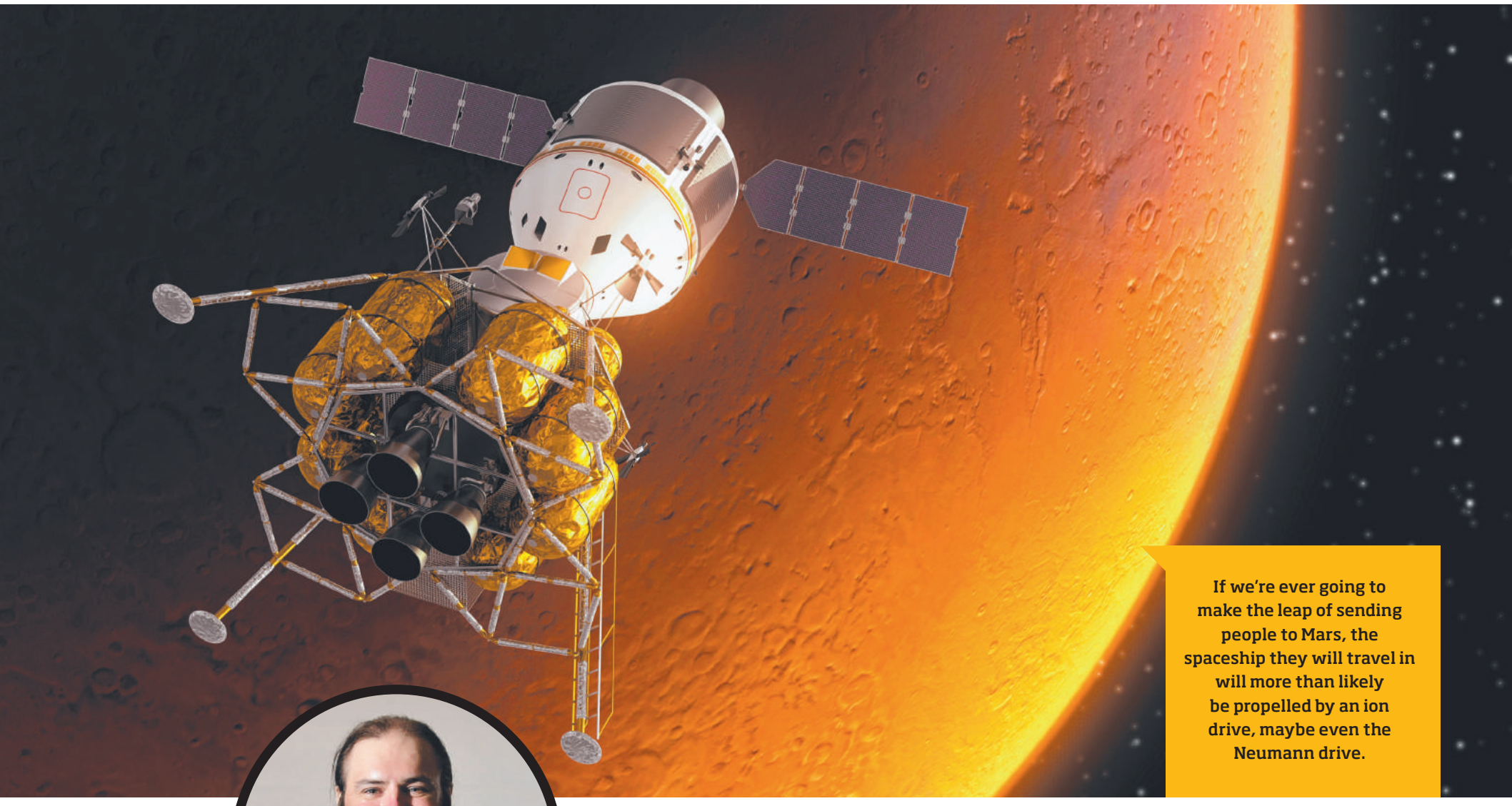


65,000 OF HISTORY

Artefacts excavated from a rock shelter near Kakadu National Park indicate humans reached Australia at least 65,000 years ago – up to 18,000 years earlier than archaeologists previously thought. Ground-edge axes, grindstones, flints and ochre were found, as well as evidence of fireplaces throughout the site. Sophisticated techniques were used to date sediments at the rock shelter.

Chris Clarkson from the University of Queensland says the new date will have a big impact on our understanding of when humans first left Africa and moved through what is now South-East Asia.

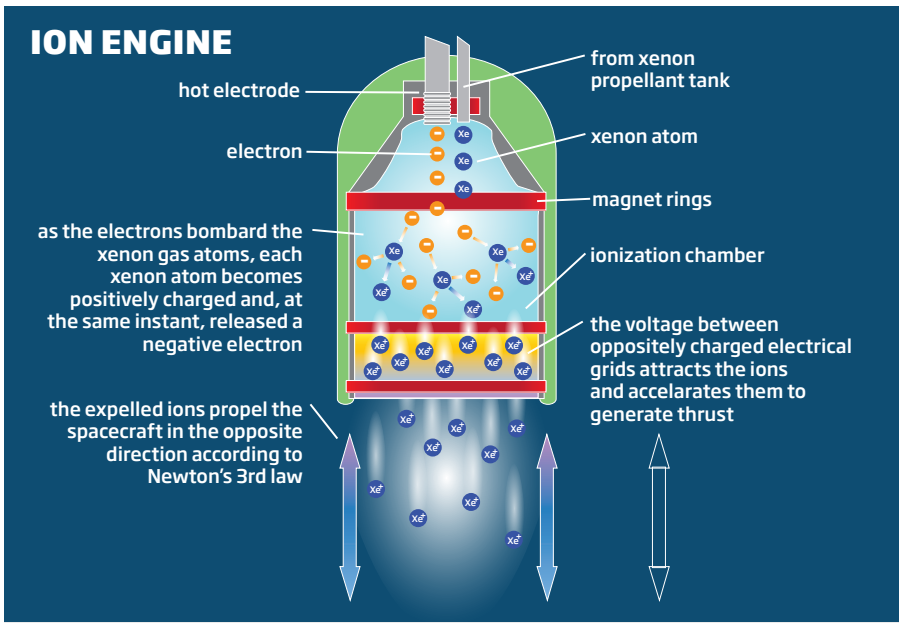
Clarkson says the discoveries demonstrate very strong cultural continuity at the site across thousands of years.



If we're ever going to make the leap of sending people to Mars, the spaceship they will travel in will more than likely be propelled by an ion drive, maybe even the Neumann drive.

ION MAN

The opportunities for the future of the space industry in Australia are vast but, for **Dr Patrick Neumann,** it's all about the rocket science



THE GREATEST CHALLENGE for space exploration is fuel, or the weight of that fuel, says Adelaide-based space propulsion expert Dr Patrick Neumann. For a return mission to Mars, for example, 96 per cent of the weight of a conventional chemical fuel spacecraft is the fuel itself, leaving little spare for cargo or crew.

Modern ion engines – very low powered but able to slowly accelerate a spacecraft through space – are fuelled by gas that would make up 50 per cent of a spacecraft's weight on its way to Mars.

Neumann believes he can do better. His invention can potentially reduce the fuel payload to just 30 per cent of the total available mission weight and that fuel could be simple magnesium.

His ion engine is essentially an electric arc-welder. In an arc welder, when the negatively-charged cathode welding rod gets close enough to a positively charged anode lead clamp, an arc of electricity "sparks" by ripping electrons off the air molecules between them. The cathode rod gradually wears down as some atoms turn into plasma and are carried off by the jumping electrons and deposited in the weld.

In the Neumann drive, the cathode rod itself is the fuel. Neumann says the plasma this produces provides higher exhaust velocities than existing ion engines, giving the drive more thrust for its weight (otherwise known as specific impulse). It also has far fewer complex components.

Magnesium is one of the most common metals in the universe, making it a cheap fuel source, although the Neumann drive can use any metal, even recycled space junk, as fuel, Neumann says the space industry will create a high demand for a broad spectrum of STEM skills.

"By bringing all of these skill sets together, we can create new products and services that benefit people all over the world," he says.

"Every system on the spacecraft – guidance, navigation, power, control systems, propulsion, thermal management – needs people to design, build and troubleshoot to make it all happen. Every system on the ground – mission control, ground stations, sensor calibrations, project management – needs talented people just as much."

FUELLING THE DRIVE

Things the scientists have tried:

Molybdenum
Our fastest fuel - best for sending people to Mars

Magnesium
Our most efficient fuel - best for sending equipment on long missions

Aluminium
Best for recycled space junk

Carbon
Our most interesting fuel - reusing human waste from astronauts to get them to where they're going

Tin
A pretty poor fuel that they learned a lot from

Bismuth
The most useless fuel ... just don't bother

MORE ON ION ENGINES

nasa.gov/mission_pages/dawn/news/dawn-20070913f2.html
NASA resource on ion engines.

neumannspace.com
All the science behind Dr Patrick Neumann's revolutionary ion engine.

dawn-mission.org/mission/ion_engine_interactive/index.html
Interactive simulations that show you how ion engines work

wired.com/2015/10/whatd-make-better-rocket-nuclear-ion-engines/
Article on what makes a better rocket: ion or nuclear propulsion?

GOING TO SCHOOL ON MARS

SEARCHING FOR LIFE on the Red Planet in a simulated mission to Mars is helping school students discover careers in science, technology, engineering and maths.

The Mike Roach Space Education Centre at Hamilton Secondary College in Adelaide opened to students across Australia in September 2017. Assistant principal (STEM and Learning Technologies) Caroline Johnstone says students find space school "the most immersive learning experience; they really get involved".

"Students act in a different roles, so we have physicists, chemists, geologists, biologists, engineers and a mission commander," she says. "They can really see how those diverse careers apply to a situation, so when we talk about science as a human endeavour, they get to live and experience that in reality."

Students role-play space scenarios in teams, taking turns either as astronauts on Mars or scientists in Mission Control. Dressing up is part of the fun. They also collect real soil and rock samples, drill an ice core, conduct a thermal survey and take seismic measurements.

"The crater here is a replica of one we know about on Mars," Johnstone says. "All the different rocks they uncover on the simulated surface are rocks we know exist on Mars, so it's a very real experience, very authentic experience."

Hamilton Secondary College is the only school in South Australia with a designated facility and specialist curriculum to lead space education. The facility is modelled on the successful and fully booked Victorian Space Science Education Centre, which opened 2006.

The Mission to Mars is available to groups of 12 to 24 students in Years 6 to 9 at a cost of $35 to $45 each. Visit hamcoll.sa.edu.au/curriculum/space-school/ for more information.

THIRSTY ROCKS

Most of the water of Mars has evaporated and its rocks may be to blame. Billions of years ago it is thought that Mars may have had just as much water as the Earth, but variations in the chemistry of Mars compared to the Earth may have meant that its rocks sucked up the water present before it could sink under the surface of the planet.

Danish astronaut Andreas Mogensen tests the space suit on the International Space Station. Picture: European Space Agency

A SKIN-TIGHT SUIT WITH

THE RIGHT STUFF

WHEN HE'S NOT keeping fighter aircraft and Unmanned aerial vehicles aloft, aerospace engineer Dr James Waldie is busy researching ways to protect astronauts on manned space missions. The idea of missions to space and other planets inspired Waldie, even as a child. He pursued an aerospace engineering degree with RMIT before getting to work on a space suit that seeks to mimic the effects of gravity on an astronaut.

"Towards the end of my science course, I started to look into ... the physical deconditioning astronauts suffer – it's really quite profound," Waldie says. "Our first thought is that space flight is just this wonderful, floating, euphoric experience but in fact it's a really challenging environment for the health of humans. There are radiation impacts and the lack of gravity has negative impacts on the body and almost all the physiological systems: bone density, muscles, heart condition, eye-sight, taste.

"When agencies look at long-duration manned missions, the technology isn't the limiting factor, it's keeping the crew healthy. Our bones and muscles are strong on Earth because they have to support and move our heavy bodies. In space, the body becomes weaker very quickly just floating around."

Waldie focused his PhD on the suit design to counteract the effects of weightlessness in space by simulating the effects of gravity.

"This was about at the time of the Sydney 2000 Olympics and there was a lot of talk about skinsuits – the swift suit that Cathy Freeman wore, the shark suit that Ian Thorpe wore," he says. "I wondered if we could engineer a skin suit to reduce the deconditioning of astronauts. Bone loss seemed to be an application. I wondered if it was possible to reapply a gravity-like loading on the body then perhaps we could trick it into thinking it was still standing on Earth, therefore it would stay healthy. My idea was to engineer what we ended up calling a gravity-loading counter-measures skinsuit."

Adding mass to a body in space has no impact on its weight because mass is weightless without gravity. He says he aimed to load the body vertically by trying to make it shorter, adding loading from the shoulders down to the feet, just as when we stand up on Earth. "We do that by engineering a gradually increasing stretch in the suit from shoulder to feet," he says. "The suit is highly customised to each astronaut."

After his PhD, Waldie did a post-doctoral fellowship at MIT in the US, working with NASA and the European Space Agency (ESA), refining and validating the suit design using many tests. "The first major test was in a parabolic flight campaign on what they call the vomit comet," he says. "The plane flies in big arcs to simulate micro gravity and weightlessness. You go from zero-g to high-g and back – it's quite nauseating to do it. That was a great experience.

"We continued to work with ESA and refined the suit through six iterations. It went up in 2015 ... we were at the European Astronauts centre in Germany, and we watched the monitors of the astronaut who first wore the suit. The suit went up again in 2017."

Compared to existing countermeasures, such as treadmills, Waldie says the main advantages of the suit are that it is very light, requires no power and astronauts can still do their work in space while wearing it. He continues to consider the suit's wearing protocol as a co-principal investigator with the ESA. He is also an adjunct principal research fellow at RMIT.

When agencies look at long-duration manned missions, the technology isn't the limiting factor, it's keeping the crew healthy

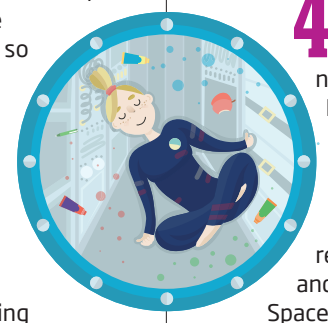
HUMAN BODIES IN SPACE

In space, many things endanger or affect the human body.

1 NASA has learned that without gravity working on your body, your bones lose minerals at a rate of more than 1 per cent a month. By comparison, the rate of bone loss for elderly men and women on Earth is from 1 to 1.5 per cent a year. Even after returning to Earth, your bone loss might not be corrected by rehabilitation, so you could be at greater risk of osteoporosis-related fractures later in life.

2 The lack of gravity means you will lose muscle strength and endurance and experience cardiovascular deconditioning if you do not compensate. The fluids in your body will shift upwards to your head, which could put pressure on your eyes, causing vision problems. You may develop kidney stones because of a lack of hydration and increased excretion of calcium from your bones.

3 Medications react differently in your body in space and NASA has learned microbes can change their characteristics in space. Micro-organisms that naturally live on your body are transferred more easily from person to person in closed habitats like the Space Station. Your stress hormone levels are elevated and your immune system is altered, which could lead to increased susceptibility to allergies or other illnesses and disease.



4 On the ISS, astronauts receive more than 10 times the radiation than naturally occurs on Earth. Exposure may increase your cancer risk and damage your central nervous system, manifesting itself as altered cognitive function, reduced motor function and behavioural changes. Space radiation can also cause radiation sickness and you could develop degenerative tissue diseases, such as cataracts, cardiac and circulatory diseases.

5 The food you eat and the medicine you take must be safe and retain its nutrient and pharmaceutical value, even while being bombarded with space radiation.

SOURCE: NASA
nasa.gov/hrp/bodyinspace

The extreme gravity unloading in space means you grow in height. Astronauts can grow up to 7cm taller during a stint in space. You experience this on Earth as you sleep at night. When you lie down, you unload your body vertically. Measure your height before you go to bed and when you get up, you're about 2cm taller.

LIFE ON MARS

Dr James Waldie is also a member of the Mars Society of Australia, which has given him further scope to test out his space skin suit. "You can also use skin suits as advanced technology for doing a spacewalk," Waldie says. "Instead of having a big suit filled with air - if you puncture it, it's a full-body depressurisation - the skin suit can compress you into the same pressure as a normal spacesuit. You have a helmet with breathing oxygen and the skin suit matches the pressure over the rest of the body. It's a lot lighter and more flexible and safer because if you scratch it, it only affects that part of the body." He says as part of the Mars Society, an analog suit has been designed that, when worn here on Earth, replicates what it would be like to wear the real space suits on Mars. "We do all these really nerdy cool things and go to a Mars habitat re-creation in the Utah desert and we live there, but it's like living on Mars," he says. "If you go outside you have to put on your space suit and go through an airlock and ride on your ATVs and explore the landscape as a real astronaut would." He says real astronauts would wear an extra garment on top for protection against temperature extremes, micro-meteorites, radiation and abrasion.

EYES IN THE SKIES

DECADES OF DATA from satellites circling the globe is now available free of charge through a new analytical tool called Digital Earth Australia. The world-first analysis platform can be used to answer all sorts of questions about how the landscape has changed over time. Chief of the Environmental Geoscience Division at Geoscience Australia, Dr Stuart Minchin, says you can explore more than 30 years of history in scenes "stacked up through time".

"You can then look for things like where was the water, where was the green vegetation, where was the bare soil, how has the coast changed, what has been built on, what has been cleared, what are the changes in crops and those sort of things," he says. "So you've got this big data tool you can throw questions at and get answers."

Minchin says it was an enormous technical challenge to clean and prepare the data for analysis, but now the hard work has been done and the entire data set is "analysis ready". The team is now working with government and industry to make new tools for customised use.

"We see many, many applications," Minchin says. "There are many opportunities for budding entrepreneurs to actually take this information and turn it into services for the general public."

BEHIND THE SCENES Cleaning the data was a complex mathematical challenge that had to be overcome before the satellite data could be used effectively. Every scene must be corrected to enable comparison over time, turning the information recorded by an Earth-observing satellite into a measurement of the characteristics of the surface of the Earth. This accounts for complex variations in the atmosphere, sun position and view angle at the time each satellite image is captured. It also indicates where the image contains missing data, has been affected by cloud or cloud shadow, or has been affected in other ways.

EXISTING PRODUCTS

The Water Observations from Space is the world's first continent-scale map of the presence of surface water. It highlights where water is normally present (blue, green), occasionally observed (yellow) or rarely seen (red). Helps us to understand flood risk.

Fractional Cove splits the landscape into three parts, or fractions: green (leaves, grass, and growing crops), brown (branches, dry grass or hay and dead leaf litter) and bare ground (soil or rock). Applications include monitoring of pasture for grazing and stocking rates.

Normalised Difference Vegetation Index assesses the extent of living green vegetation across the continent. A sudden drop may reflect land clearing, cropping or bushfire. A sudden rise may indicate higher water availability, crop growth or the greening of irrigated pasture.

The Intertidal Extents Model provides information about the area between land and sea from highest to lowest tide. Applications include habitat mapping in coastal regions, monitoring for migratory birds and hydrodynamic modelling.

When fully operational, Digital Earth Australia will provide new information for every 10sqm of Australia, every five days.

Associate Professor Ronika Power examines an ancient Egyptian mummified human head. Picture: MQ Mummies Project

How do scientists learn to love their subject area and get ahead in their field? Four scientists from the STEM fields of SCIENCE, TECHNOLOGY, ENGINEERING and MATHS give us their answers to these questions

IS FOR SCIENCE

Associate Professor Ronika Power teaches and researches at Macquarie University in the fascinating world of bioarchaeology, fusing the fields of biology and archaeology with ancient history and culture

Q What is your primary field of research?
It's something called biocultural archaeology. It's combining data about bodies, the lived experience from the past, with artefacts, tombs, art, architecture, diet – any evidence you've got from the ancient world. I take it and combine it with data from the bodies to arrive at a more holistic view of the lives of individuals and groups from past populations.

Q Which STEM subjects did you study at secondary school?
I did biology and mathematics at school and I absolutely loved biology. I've been fascinated by the human body and the way it works – its extraordinary structures, mechanisms, design and its ability to grow and heal. I also studied mathematics, a very important foundational subject. My interest in ancient history started then and I could see how they could be used together to arrive at new ways of seeing the world.

Q How did you get involved in your work?
I was always very curious about what happens to bodies once they stop living and then how different cultures deal with the biological imperative of death – we know that at some stage we will all die. I can remember as a child reading (about) the Pyramids of Giza as the tombs of the pharaohs and I was enraptured by Ancient Egypt.

Q Which university qualifications did you pursue and why?
(Illness) meant I wasn't able to go straight to university. I developed a career in business management ... until I was about 26. At that point, the call of the mummies and the tombs became too strong. I became an undergraduate university student to follow my passions. I did a Bachelor of Ancient History (but) I studied as much science as I did ancient history. My honours degree and PhD research has all been an intersection of biological anthropology (studies of ancient human bodies) with history, archaeology and philosophy.

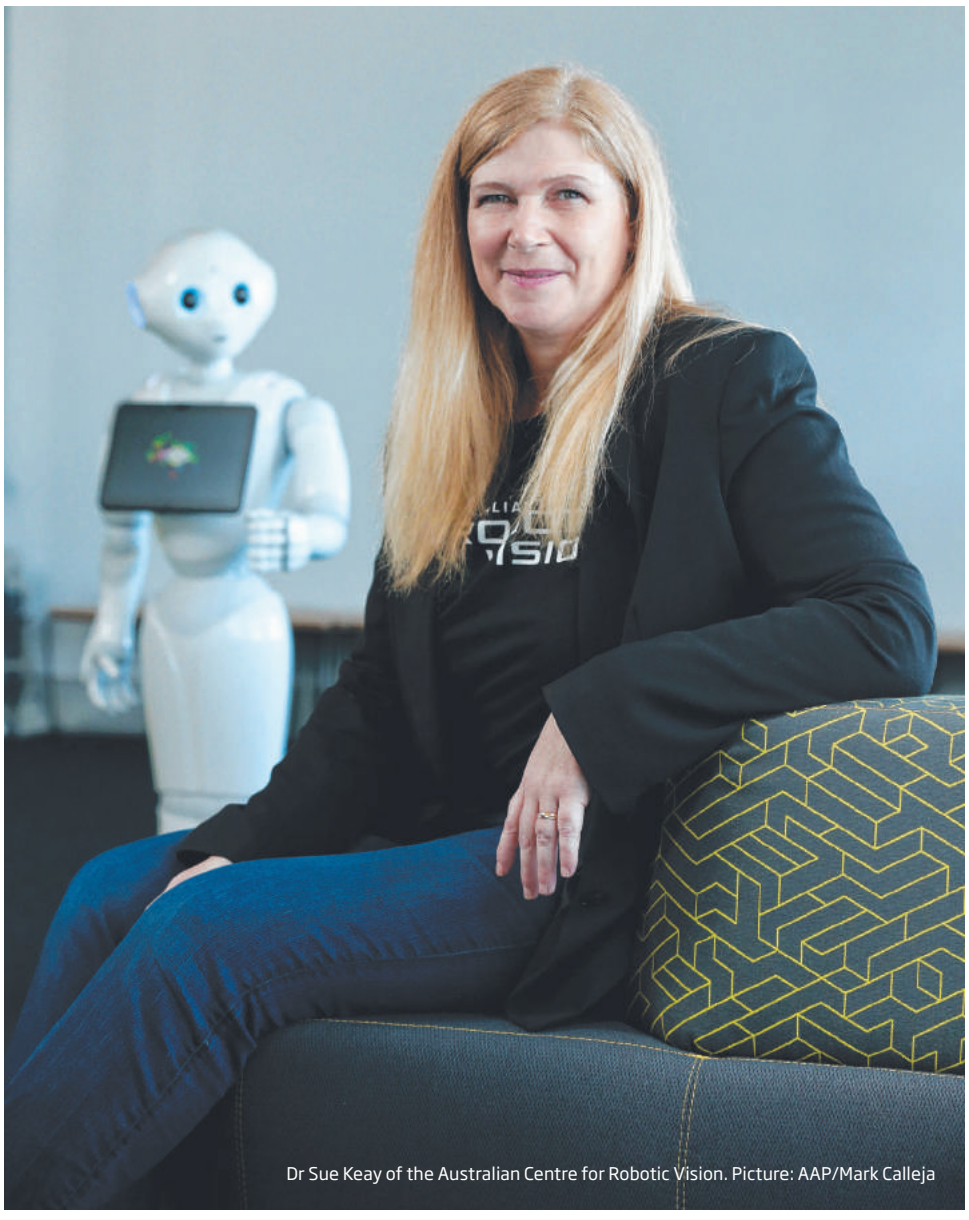
Q Which places have you travelled for your work and how much is field work?
One of the beautiful things about my job is that we travel to a lot of interesting places. I go to archaeological digs – I was at one in Egypt at the end of last year at the Temple of Dendera. I've worked in Lebanon, in Britain and on remains from places all over the world, including China, Benin, the Maldives. About 30 per cent is field work. In the field, there's nothing like seeing someone's face for the first time since they were buried thousands of years ago.

Q What are the hazards of your profession?
We take care to abide by laboratory rules in the field, in order to protect ourselves and the ancient individuals we're working with. We have to be very careful dealing with chemicals. Thinking about international travel, we have to be realistic and, no matter where you are in the world, you can be at risk. You need to think about vaccinations, documentation, visas, currencies, language and be a confident, courageous and intrepid traveller.

Q You have spoken about integrating arts and science. How do you combine them in your work?
By working together, we are going to achieve so much more. We need to be able to talk about science in its broader cultural context in the world. It's much more fun and exciting. I would never recommend that if people have broad interests that they narrow them. We don't know what the future holds and maybe the keys to the great discoveries are going to be about bringing many disciplines together.

T IS FOR TECHNOLOGY

Dr Sue Keay is working towards a future where robots can safely interact with humans



Dr Sue Keay of the Australian Centre for Robotic Vision. Picture: AAP/Mark Calleja

Q Describe your current role.
I run the Australian Centre for Robotic Vision in Brisbane. We are trying to apply the science of computer vision to robotics, so that we can create robots that can see in a similar way to the way humans see the world. We don't think robots can really work safely side by side with humans until they see the world around them in the same way humans do. We're a national research centre and our computer vision specialists are in Adelaide. They are leading the world in a lot of this work.

Q What is the best thing about your work?
I get a peek into the future because a lot of the things we're doing in the lab you don't see in the world yet, but they are going to be making a big difference when they're widely adopted.

Q How close do you think we are to having the robots alongside us?
In a lot of areas they're already here – if you have a robotic vacuum cleaner in your house, for example. In some hospitals – and I think Adelaide is pretty advanced – you already have robots that are delivering meals and linen, transporting materials around the hospital. They don't really interact much with humans at this point. It'll probably be another five to 10 years before you see robots in front-of-house roles. You find robots in warehouses and factories but we're just really starting to scratch the surface of what they can do.

Q How did you decide what you wanted to do with your life?
I think that's something that's constantly changing. Robotics is certainly an area that's just booming at the moment so it's fascinating to be involved. I come from a family of early adopters ... we were one of the first households with a personal computer. I grew up in a home where, every time there was a new advance in computing, my family were the beneficiaries of that very quickly.

Q What do you predict for the immediate future of robotics?
It's not beyond the realms of possibility that, when my children are my age, we'll have a lot more cybernetic systems where machines are integrated with people, to enhance our capabilities. Some people at the moment (are) already putting implants in rather than using an iPhone or using an external device – you can swipe your wrist over a reader. We'll be guided by what people want.

Q What did you study?
I was originally a geologist. I did a Bachelor of Science with honours at the University of Newcastle, NSW, and a PhD in Earth Sciences at the Australian National University.
I'm currently completing my MBA at the University of Queensland.

Q How does this help?
Any scientific degree gives you an understanding of the scientific method. That means you can really cast a critical eye over any new idea or technology and have the confidence that you can figure things out.

Q Why an MBA?
You can always learn new things but it's important to balance science with an understanding of the business world, where soft skills like communication are extremely important.

Q Where are the big employers in this area?
A lot of engineering firms do automation; there are lots of opportunities in robotics here in Australia. There are predictions we'll all have different titles for jobs as we go through our lives, so it's more about getting those basic principles, an understanding of scientific method so you can then apply it to anything.

IS FOR ENGINEERING

As a design manager for a consultancy company, **Felicity Furey** enjoys the chance to turn ideas into reality

Q Describe your current role.
As a civil engineer, at the moment I'm working on the West Gate Tunnel Project, which is a big road and Melbourne's first new road tunnel in a decade. Part of the thing that's cool about the role is to make sure people travelling on the road get to their destination safely. No matter what we do as engineers, there's always something we're creating to help people, and I think often the "why" we're doing projects gets missed out. I'm a design manager so I review the designs and the reports.

Q What is the best thing about your work?
I love seeing the designs I've worked on happen and appear in real life, going "I helped build that" or "I made that happen". Part of engineering is it's such a team effort, with so many people working on a project. You're always working in a team environment. My strengths are more in working with people and big-picture ideas, so I think it's important you have a whole variety of people working together to make these solutions, to make these designs and create these projects.

Q How did you decide what you wanted to do with your life?
Growing up, I wanted to be an inventor but I thought you had to be really smart and I wasn't sure how I would do that. My parents said, "Pick subjects you like, do your favourite ones" and I loved art, ancient history and physics. When I got to Year 12, I still didn't know what I wanted to do but then my physics teacher suggested engineering. It wasn't until my second year of uni, when I could see how maths and science was applied, that I really enjoyed it.

Q What did you study?
Bachelor of Engineering (Civil) at QUT, Brisbane, and Diploma of Project Management, Australian Institute of Management.

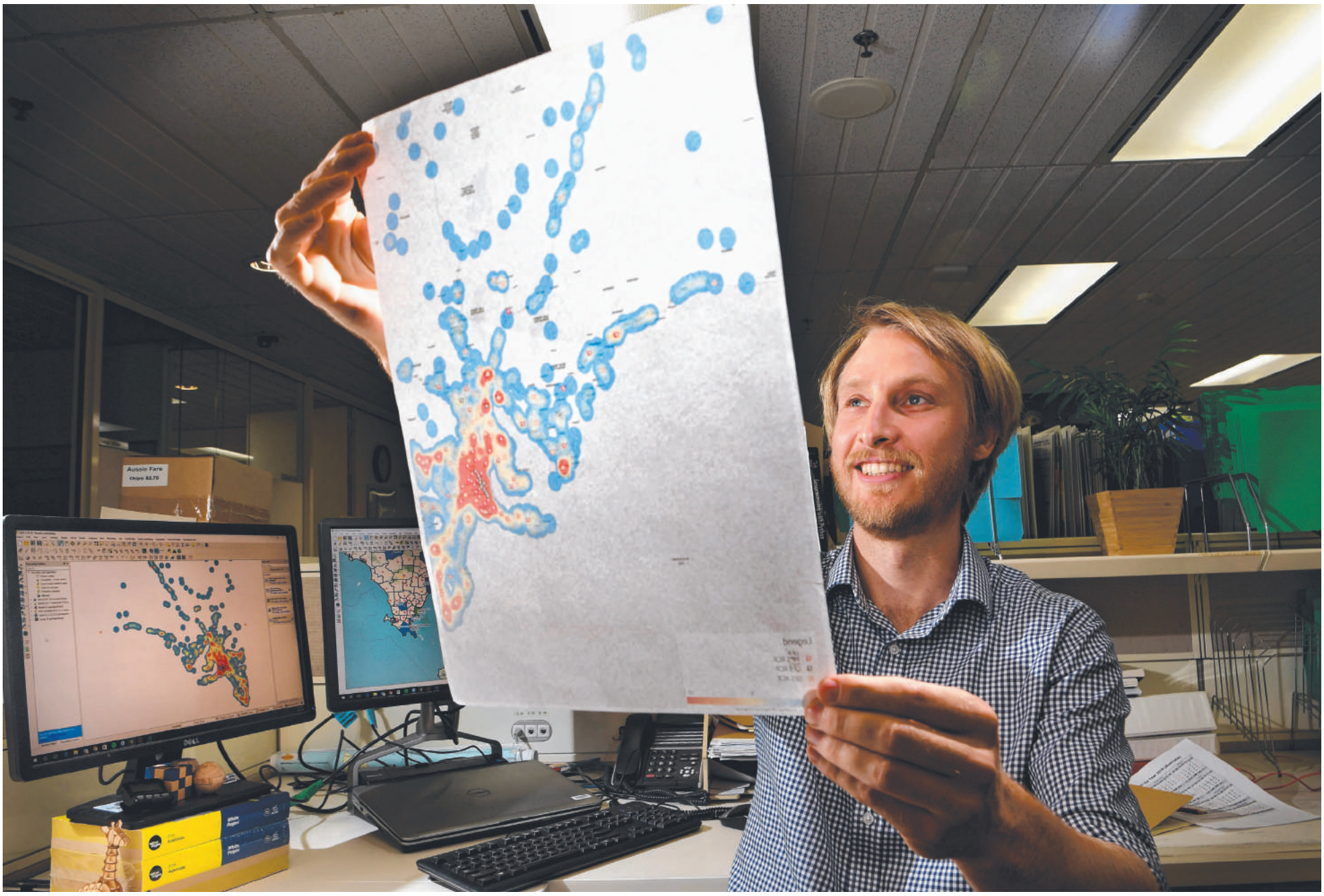
Q How does this help?
We covered a huge variety of topics, like geotechnical engineering, transport, water, structures, concrete design, steel design. I think an understanding of all the basic elements that go into an engineering project is really helpful but, fundamentally, at the end of it, all the subjects you're doing are teaching you how to think, analyse, problem solve – to think creatively about solving problems.

An engineering degree, no matter what discipline, gives you a great foundation in a huge number of careers. I think something like 21 per cent of CEOs are engineers. So it's not just going into a traditional engineering job, where you're designing something or you're a project manager going into a consultancy. They love engineers because of the way engineers think.

Problem-solving skills are really important for business as well as engineering.

Q Can you offer any advice to young people considering future careers?
I would say don't try to be anyone else; be you. That sounds like a cliche but every person has their own gifts and unique strengths. While I found maths really hard and engineering quite challenging, I could see what the end result would be. I think I spent a lot of the time doing engineering trying to be like a really amazing maths and science person, but then I realised being someone who works well with people is actually really helpful in engineering. I wish I had spent more time learning my strengths earlier and understanding myself more to pair that with my engineering degree.

**Furey created not-for-profit organisation Power of Engineering, as well as online maths teaching resource Machinam.*
Visit: powerofengineering.org
Visit: machinam.com



M IS FOR MATHEMATICS

Dr Martijn van der Merwe uses maths to solve tricky problems and put resources in the right places as operations analyst; standards of fire and emergency cover at the South Australian Country Fire Service

Q Describe your current role.
Strategic planning, taking a risk-based approach to resource allocation. That includes the equipment and skills required to respond to road crashes, hazardous material spills, structure (building) fires and bushfires. I look at where the risk is and where the response is and then try to reallocate resources. I also get involved when the heat is on– when there is a total fire ban or a major fire burning, I become "activated" to perform my secondary role, as a logistics support officer within State Command Centre.

Q What is the best thing about your work?
Independence – being able to investigate different ideas. I enjoy having a say about what you do and how you do things in this role. It is definitely intellectually challenging, because these are complicated problems. That's also where a mathematics background comes in, because at some point you come across a hard problem and want to solve it. You're dealing with people as well – a lot of things that are tricky to model.

Q How did you decide what you wanted to do with your life?
I remember when I decided to do science: I was reading a book by Richard Dawkins – he's a bit of a controversial character – but I thought, "Science is interesting; I'm going to do biology". Then in first year at university I realised maths was more my thing. I was trying to keep the link with the natural world so initially I studied biomathematics, which is a real growth field. That's how I steered into wild fire. I thought, "That's cool. That links the natural world with mathematics".

Q What did you study?
PhD in Mathematical Sciences with a focus on Operations Research at RMIT University.
Masters of Science in Operations Research, Stellenbosch University, South Africa.
Honours in Mathematics with a focus in Biomathematics, Stellenbosch University.
Bachelor of Science (Physical and Mathematical Analysis), Stellenbosch.

Q How does this help?
Part of it is the way you think about problems. Your background changes how you see the world a bit. A maths background gives you an analytical approach to things. It's that modelling mindset: "How can we model this? What are the quantifiable factors?"

Q What does a career in maths have to offer?
It's a great area. It gives you a lot of scope to go into different areas. If your teacher matches your way of learning, everything becomes clearer.

Q Where are the big employers in this area?
Some areas are well crafted, like financial mathematics and stock trading – it's pretty likely you'll find work at the end of that because the skills are in high demand. But in other areas it's a more winding road – you've got to find your own path. It's a good thing, but it's a bit harder. You have to dig out your own niche and decide this is the area I want to specialise in. People sometimes think if you study physics and mathematics you've got to be an academic, but that's not where most of the jobs are. You might go into animation studios or banks– or the CFS!

HELPING ATHLETES PAVE THEIR ROAD WITH GOLD

IAN BURNS WAS a sailor before he became a mechanical engineer and has spent most of his life combining his smarts with his love of yachting.

For many years, he helped develop technology to make this nation's America's Cup craft go faster until, finally, he decided to translate his skills to the Australian Institute of Sport as its deputy director of applied technology and innovation.

"On a daily basis we are trying to help our Olympic athletes perform better in their sports," Burns says. "Sometimes it's helping them, sometimes their coaches, their physiotherapists or different people in their team on how to look after their injuries or how to avoid injuries, or make them stronger or faster."

At the AIS, he has helped set new technology in motion, including real-time data from Olympic rowers as they train for their next international showdown. "We built a chain of data coming from a mobile phone in the boat, which broadcasts the data it picks up from accelerometers on how the boat's going forward in the water," Burns says.

"We can detect how fast their stroke rate is per minute. We can see ... how that compares to the world-record speed or the Olympic speed they'll need to win a gold medal. We have a database of athlete data that stretches back many, many years, from Olympians gone by. We can use it to compare how athletes are progressing."

The AIS also uses wind tunnels and computer fluid dynamics (a computer wind tunnel) to help athletes of all kinds in their quest for victory. "Cycling's a big

one for that," Burns says. "We also have our para-athletes – we put them in the wind tunnel. And we've been doing it with our winter athletes, these guys who ski race or snowboard race – the aerodynamics are a big part of their total drag.

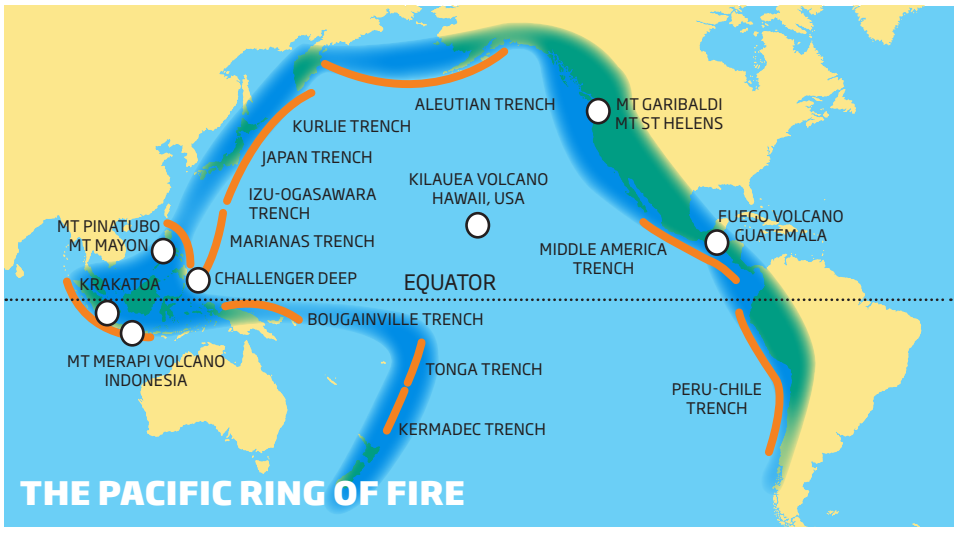
"We use a wind tunnel down at Monash University in Melbourne – we do good stuff with them either in computational and practical experiments on aerodynamic drag."

The process helps scientists and athletes reduce the drag, both on their bodies and their equipment, in order to go faster.

"Australia is pretty good at a lot of equipment sports, like sailing, rowing and cycling, so there's a lot of science and engineering in making that better, especially in para sports like wheelchair racing and tennis," he says. "We make some customised equipment that translates into pretty good performance for our athletes."

DID YOU KNOW?

The Ring of Fire is a major area in the basin of the Pacific Ocean where many earthquakes and volcanic eruptions occur. It is in a 40,000km horseshoe shape, associated with a nearly continuous series of oceanic trenches, volcanic arcs, and volcanic belts and plate movements. It has 452 volcanoes (more than 75 per cent of the world's active and dormant volcanoes). The Ring of Fire is also sometimes called the circum-Pacific belt. About 90 per cent of the world's earthquakes and 81 per cent of the world's largest earthquakes occur along the Ring of Fire.



THE PACIFIC RING OF FIRE

DELVING DEEP TO GO

WITH THE FLOW

Dr Rebecca Carey didn't know she wanted to study geology until she reached the University of Tasmania and began her undergraduate studies in science

I HAD WANTED TO be a vet, a marine biologist, a pathologist – something that would give me a role where I could investigate the natural world," Carey says. "But I really enjoyed geology at university. I enjoyed being in the field and being able to learn about rocks so that, wherever I am in the world, I only need to look at the rocks to understand something about how they came to be."

Her studies took her to Hawaii for a third-year student exchange and to opportunities to study in a far wider choice of earth science disciplines, including seismology, volcanology and chemistry. But the opportunities came at a cost. "While I was there, the Australian dollar was worth half of the US dollar. It was terrible; I had no money," she says. "I got job working for a professor at the University of Hawaii in his lab. His specialty area was volcanology.

"By becoming his lab rat I got to work with all of his PhD students doing the lab analysis they needed. Through hardship I was actually given more opportunities to learn about volcanology and how research is done."

Her honours research then took her to the other side of the world to study the last big eruption that happened in Iceland.

The 1875 Askja eruption poured out an ashfall heavy enough to poison the land and kill livestock, and triggered a wave of emigration from the tiny island nation.

"I had four years doing a triangle between Iceland, Hawaii and Tasmania. I was a gold member with the frequent flyer club, I had so many points," Carey laughs.

Further work on her PhD led to a post-doctoral research fellowship with the Australian Research Council and a teaching appointment with the University of Tasmania, and to her most challenging research to date: submarine volcanoes.

"We know relatively little about how volcanoes work underwater ... because it's hard to access them on the sea floor," she says. "We're starting to learn more now but we don't really understand how fundamentally different or similar underwater volcanoes are."

The work has centred around an eruption of an underwater volcano in a chain north of New Zealand in 2012. After gathering a huge amount of data before and after the eruption, $3.5 million in funding from the US National Science Foundation secured ship time and robotic vehicles to investigate the sea floor.

"When we got down there, we found a complicated volcanic history. Lava had probably started flowing months before we saw anything at the surface ... and parts had collapsed," Carey says.

The upshot is an understanding of a fundamental process about how our Earth works, she says: "We're trying to understand the heat and chemicals provided to the ocean, which is important because volcanoes play a really important role in mixing deep water with shallow water in the ocean."

She says the heat from underwater volcanic eruptions also sustains chemosynthetic life – organisms that produce food using chemical energy, as opposed to sunlight for photosynthesis.

This is crucial because scientists believe they might produce life-saving chemicals to cure disease, among other things. Knowledge of volcanoes also helps the mining industry because many of the minerals they seek are found in volcanic rock.

Carey says work for volcanologists in Australia is scarce because we lack active volcanoes but, for those wanting to do volcanology at an academic level, there are jobs overseas, especially in countries that host very dangerous volcanoes, including the US, Japan and New Zealand, all on what is called the Ring of Fire. She says would-be scientists should take every opportunity that's offered to them and allow themselves to explore different areas of science before settling on a career path. "Also, try and find mentors to help you through your academic and career paths," she adds. "I've had really good mentoring that has helped me with my decision making, and that's helped me find opportunities and be successful in applying for those opportunities."

THE VOLCANIC ERUPTION PROCESS

Magma, a hot silicate mixture, forms in the Earth's crust.

It is made up of molten lithospheric rocks, gases and water vapour.

It rises slowly to the surface, building up in underground reservoirs called magma chambers.

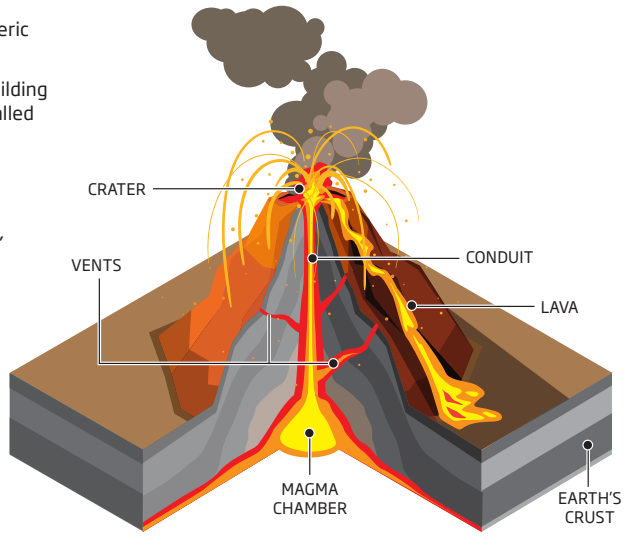
The gas pressure increases and gases begin to spew out.

The magma rises to the surface, the gases expand as the magma rises along the conduit.

The magma swells up and explodes,becoming unstable and turbulent.

The magma pulsates and explodes as it leaves the crater.

Lava, a fiery mixture of semi-molten rock, gases, vapour and ash, is ejected on to the surface with great force.



Professor Trevor Ireland is a professor of geochemistry and cosmochemistry at the Australian National University

DID YOU KNOW?

HAYABUSA2 is an asteroid exploration and sample-return mission launched in 2014. Its target is a small asteroid known as 1999 JU3, which the spacecraft reached in June 2018. After orbiting and studying the asteroid for 18 months, Hayabusa2 will send a lander to the surface to collect samples, which will be returned to Earth in late 2020.
OSIRIS-REx is a NASA mission launched in 2016.
This mission will closely study the orbital characteristics and surface features of asteroid Bennu, which it will reach this year. OSIRIS-Rex will also collect and return samples from the asteroid's surface.

UNCOVERING MYSTERY

FROM THE SKY

PROFESSOR TREVOR IRELAND will have people stampeding to his door if an asteroid ever gets on a trajectory to hit the Earth. It's the kind of doomsday scenario posited in popular movies, but one that is within the realms of possibility and one of the things that drives the Australian National University cosmochemist's work.

His work at the university and with various space agencies around the world has him studying the chemistry and composition of meteorites – a solid piece of debris from a comet or asteroid – and material from sample-return missions into space.

"Originally everybody collected their own meteorites that fell on their country," Prof Ireland says. "There's two types of meteorite – falls and finds. If you see something fall, you get this really nice fresh stone, whereas, if it's a find, it could have been sitting on the ground for ten thousand years."

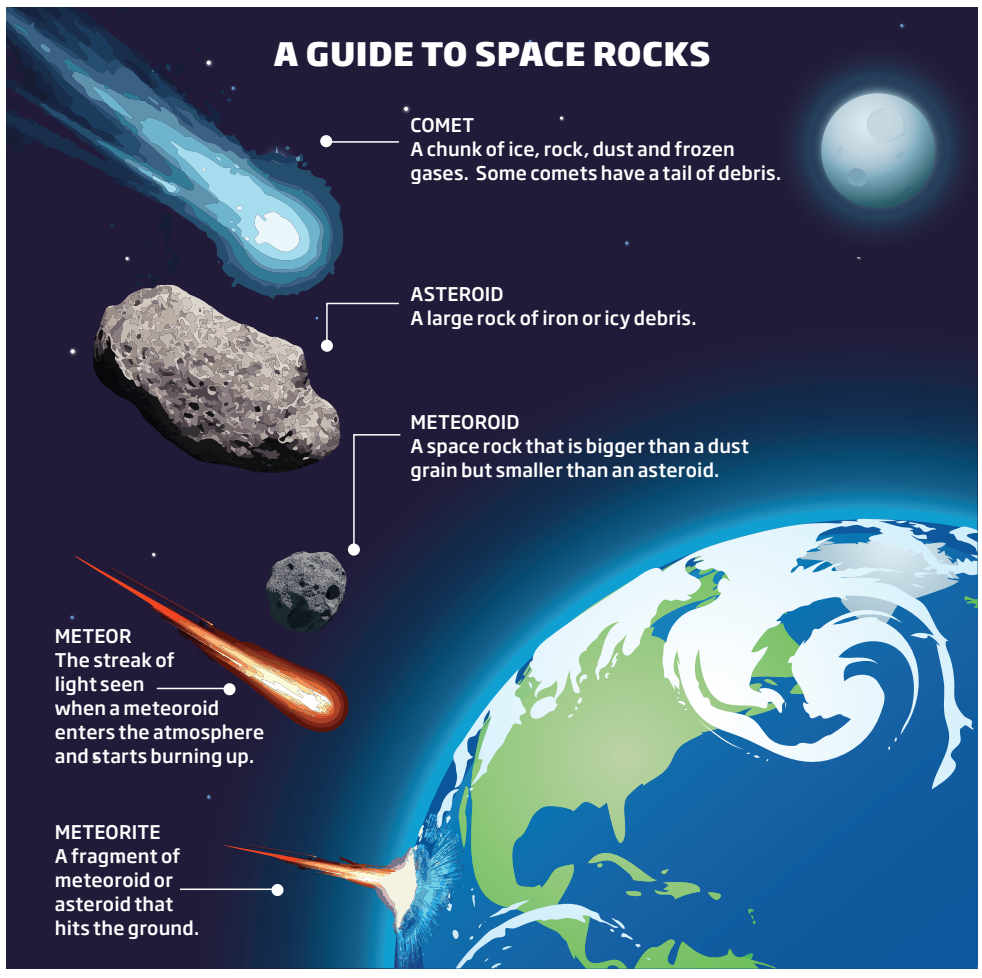
The finds are less valuable to scientists than the falls because they have been degraded by the Earth's environment, he says.

Old-time scientists went to museum collections to study meteorites but, in the 1970s, some bright spark decided Antarctica would be a good place to pick up fresh finds "because anything sitting on top of the ice should have come from above (space)".

Prof Ireland says about 20,000 meteorites have been recovered from Antarctica and, in the past 10 years, the Sahara Desert has revealed a whole different range of meteorites. What they give the scientists is information on the original building blocks of the Earth and how solar systems are formed.

"(The chemistry of meteorites) is telling us that solar systems formed incredibly quickly – 10 million years is enough to go from a dust cloud to a planetary system," he says.

"The meteorites give us the context we can't get from astronomy. Astronomy is good at giving a broadscale context but the stuff we get from meteorites gives us a micro-scale context of what's going on. The astronomy can't show us what's going on close to the star – that's where we can pick up the meteorites



and actually see that the solar system is just one of these evolving stellar systems ... we can get incredibly high precision at dating and we can see what processes are going on close to the stars as they are forming."

Prof Ireland says he grew up in the 1960s, when the space race between the US and the former Soviet Union was in full flight: "It was all about the space missions and the Apollo landings. My mother was a rock hound, so she used to drag me out collecting rocks and I was also interested in astronomy so I joined the local society. My favourite subject at school was chemistry so they melded together until I got to university."

He discovered he didn't enjoy university chemistry and took up physics instead, ending up in earth science. "I went to Antarctica as a geologist – I did both geology and physics as an undergraduate," he says. "It was sort of weird because the sun doesn't set, it just goes around your head, so you orient your tent so you're not looking at the sun at night so you have a chance to go to sleep. It's a funny environment because your floor is about -20C and the top of the tent is plus 20C, so you get condensation dripping on you. The food is just sitting outside the tent and it's all frozen, so you have frozen sandwiches for lunch."

His work with meteorites has led to his involvement in unmanned space missions, including Hayabusa2, by the Japan Aerospace Exploration Agency (JAXA) and NASA's OSIRIS-REx mission. Both spacecraft will orbit a chosen asteroid out in space, sample material from its surface and bring it back to Earth for analysis.

"It gives a better knowledge of how planetary systems form around stars and ... being able to get samples from asteroids is getting the chance to find out what asteroids are made of and what potential issues there are if one decides it's going to come very close to the Earth, or even goes on a collision course," Prof Ireland says. "If (the asteroid) is a rubble pile, you can't put a hook on it and expect (to tow it on to another course). You can't blow it up because it just goes into lots of small pieces (that might hit the Earth). How you deal with an asteroid if you think it's going to hit the Earth is fundamental to continuing the human population."

The professor says earth science is good for science students who want to apply their skills to particular fields, including the minerals industry. "The big benefit of doing earth sciences is you get an understanding of how to deal with complex systems ... you've got to make inferences much more than you do with chemistry and maths," he says. "The pathway is almost more important than the outcome. It's putting pieces of the puzzle together and designing experiments to potentially solve the problem or lead to better outcomes."


Picture: NASA

EARTH'S BIGGEST ASTEROID CRATERS

1. VREDEFORT CRATER
Free State, South Africa. Estimated width 300km.

2. CHICXULUB CRATER
Buried underneath the Yucatán Peninsula in Mexico, this 150km wide crater was created by the asteroid thought to have caused the extinction of the dinosaurs.

3. SUDBURY BASIN
Ontario, Canada. Estimated width 130km

4. MANICOUAGAN CRATER
Quebec, Canada. Estimated width 100km.

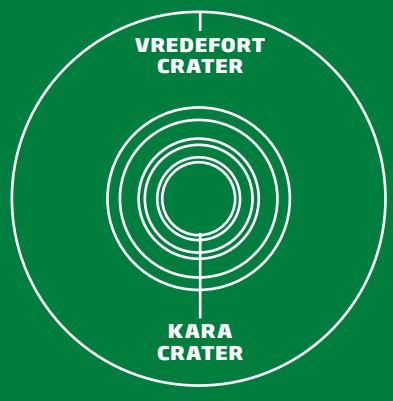
5. POPIGAI CRATER
Siberia, Russia. Estimated width 100km.

6. ACRAMAN CRATER
South Australia. Estimated width 90km.

7. MOROKWENG CRATER
Kalahari Desert, South Africa, Estimated width 70km.

8. KARA CRATER
Nenetsia, Russia. May consist of two adjacent craters: the Kara and the Ust-Kara crater. Width 65km

CRATER SIZE COMPARISON (1-8)



BREAKING THE ICE

DR AILIE GALLANT studies very old things for the most modern of reasons. The climate scientist does work in the field of palaeoclimatology, studying ancient ice cores, the rings in old-growth trees and even coral to understand how the Earth's climate changed in a time long before there were thermometers, satellites and weather radars.

"We have to try and piece together clues from other things that record what the climate did and those things are natural phenomena. Ice cores from Antarctic and glaciers, they record chemical signatures that tell us what the temperature and rainfall was like," Gallant says.

"I've also used tree rings. Many trees grow, setting down annual layers, and depending on how much the tree grows you can correlate that with the climate.
Also corals do a similar thing."

She pieces together the evidence to build a picture of the climate from hundreds and even thousands of years ago. "That's useful for putting present-day climate change into a longer-term context," she says. "We can use the different records to help us understand why the climate cycled as it did – was it volcanic eruptions, was it changes to the sun – and how does that differ to what we see today."

The only limit to her studies is the age of these "natural thermometers", with the oldest ice core covering 80,000 years of history. Gallant says an expedition to eastern Antarctica this summer secured an ice core likely to go back about 2000 years. She was scheduled to go on the journey but instead took time off to have a baby.

"At the moment, there's a project trying to get a million-year-long ice core but it's at the very start of that," she says. "I'm more interested in the past 1000 years, which is when human-induced climate change is happening."

Gallant loved science and was always "a kid who was outdoors and really enjoyed nature". "We did a lot of hiking, a lot of skiing, so I was always out in the elements. In high school I took some science subjects and really enjoyed them," she says.

Her fascination took her through romances with physics, aeronautical engineering and astrophysics, before lighting upon atmospheric science at university.

"I was encouraged to take a broad range of subjects to see what I liked and one of those was atmospheric science, although I'd never even heard of it before," Gallant confesses. "I loved it. I decided this whole weather and climate thing is absolutely fascinating. They showed us all this stuff about how storms work and tornadoes and cyclones."

She now describes herself as a climate scientist with a background in meteorology, based at Monash University as a research fellow. She advises students to keep their options open: "There are so many fields of science that, as a high school student, I had no idea existed. If you decide to study science at university, try different things.

"Also, keep up with your mathematics. You don't know what it's useful for until you use it. Mathematics is everywhere – everything we do is rooted in mathematics and it's not as scary as people think. That's coming from someone who was never a good maths student and who now has a PhD in applied maths."


Scientists work with an ice core in Antarctica.
Picture: Australian Antarctic Division

RICH PATHWAYS TO

SOLVING PUZZLES

The world is knocking on the doors of Australian universities in the hunt for computer science graduates, and it's prepared to pay for good skills

Professor Anton Van Den Hengel is director of the Australian Institute of Machine Learning, and lectures at the University of Adelaide's School of Computer Science.

AS FAR AS Professor Anton Van Den Hengel is concerned, students who don't study computer science will miss out on both a chance to shape the future and a better, more lucrative career.

"The reality is that employers are looking for people who have domain expertise (in any field) and computer science skills," he says. "I run a research group who study machine learning. There's an incredible demand for people with those skills – a mind-boggling level of demand – to the point where the standard starting salary for a graduate who is willing to travel is about $US300,000 ($A400,000)."

The professor says computer science – the basis for machine learning – is an incredibly flexible degree and one that can be applied to many fields. "It doesn't matter what you want to do in your life – save the rainforest or be an astronaut or an accountant," Prof Van Den Hengel says. "Whatever it is, it's going to involve a lot of interaction with computers. The big thing about having computer science skills is that you are not just a user of that technology but you're a creator of that technology.

"Now you can take even rudimentary programming skills and create something that's never been done before. The tools for creating apps and machine learning and interacting with huge amounts of data, the cloud, are so much better."

The professor came to computer science via maths, physics, chemistry and French in secondary school, and a degree in maths and law at Adelaide University, followed by a Masters in Computer Science and a PhD in Computer Vision, making the switch around an opportunity to research artificial intelligence.

"I could see there was a transformation coming and that everything was going to be computerised, including the law," he says. "An academic in computer science had a project about recognising chromosomes in microscope images. It seemed like such an interesting puzzle to me, I decided to do a Masters degree and, once I was hooked, I was hooked."

Prof Van Den Hengel says computer science is essentially about the art of solving puzzles by using the things a computer is good at to find a solution. He says for people terrified of mathematics, the best thing is to convince yourself otherwise.

"Maths, I think, is largely a confidence trick," he says. "The main thing about being good at maths is to believe you're good at maths. Maths at university is incredibly creative, free. It's almost artistic, the way you have to find creative ways to solve problems."

He says students these days have the opportunity to study a Bachelor of Computer Science or a Bachelor of Advanced Computer Science, although few graduates reach PhD stage because international companies offer them internships as undergraduates.

"The students go over and spend their summers working in the US and then they get offered a job for $200,000 in second year, so they come back and finish their third year and go back and take up the job instead of doing a PhD," he says.

"The competition for good computer science graduates is so hot. It amazes me that we don't have thousands of school students banging on the door begging to do computer science degrees."

CAN MACHINES REALLY TELL US IF WE'RE SICK?

US scientists have developed an algorithm, or a computerised tool, to identify skin cancers through analysis of photographs. The new method scans a photo of a patch of skin to look for common and dangerous forms of skin cancer. The scientists report their approach performs on par with board-certified dermatologists to distinguish two forms of cancer keratinocyte carcinoma and malignant melanoma from benign skin lesions. The diagnostic tool is based on a powerful type of machine learning that extracts information from images. The critical factor in achieving the accuracy required is the large volume of training data the authors have used, consisting of 129,450 skin images and a label for each that indicates whether it contains a cancerous region. The machine is trained on this data to make the distinction automatically, and can analyse images taken with a simple handheld camera, such as on most phones. This means a GP or patient could take a photo of a patch of skin and receive an indication as to whether it contains a cancerous region.

ARTIFICIAL INTELLIGENCE (AI) FOR DUMMIES

"THERE'S A LOT of talk about AI, robotics, machine learning and deep learning, as well," Prof Anton Van Den Hengel says. These are all terms that are misunderstood and abused.

"AI is trying to solve problems humans consider difficult," he says. "The whole field has this problem that intelligence isn't really defined and, if you can't say what intelligence is, it's very difficult to say what an artificial version of that would be. When people think of AI, they think robots that wash dishes and drive cars, but AI is much closer to machine learning.

"The key idea of machine learning is that you might tell a computer how to do something by example, rather than by giving it a recipe. Normally you give it an algorithm or a recipe, but with machine learning you give it a bunch of examples of what you want done and it has to figure out how to do it itself."

The professor says that's fantastic for solving problems like recognising objects in images, which humans are incredibly good at but can't tell you how they do it. "An iconic problem was recognising images of dogs and cats. Humans are so good at it – they can't not do it. (But) we can't tell other people how to do it and it means we can't tell a computer how to do it," he says.

One solution to the problem is machine learning, where you provide a computer with many images of cats and dogs and it learns to make the distinction by itself. You keep feeding these training images to the algorithm and it keeps getting better, until it winds up being better than a human.

"It's one of the core capabilities behind driverless cars. The machine has to recognise what's in front of it in order to make decisions about where to drive and when to stop," he says. "People are using it already. When you type something into Google, it gives you 10 results filtered by machine learning. The same with Facebook, about which of the billions of posts available come up on your feed. Amazon has tens of millions of products online and, to help you find the one you want to buy, they use machine learning."

RESEARCH PROJECTS

The Australian Institute of Machine Learning at the University of Adelaide has a large number of projects under way. Some are pure research, just to advance the field of machine learning, and some are done for companies to solve particular problems. The institute has had research funded by Google, Facebook, BHP, BAE Systems (aeronautics, defence, future tech), Canon (imaging and optical products) and Bayer (health care and agriculture). It is currently working with Microsoft and Stanford University on solving computer learning problems.

The institute has and is working on developing a methodology to measure the carbon content of the landscape, which is intended to help fight climate change. It has worked on five devices, including one that is based on the idea of the "tricorder" scanner from *Star Trek*. "It's a handheld device you can point at someone and have it tell you a bunch of things about them right there and then, and help make a medical decision that might save their life immediately,"
Prof Anton Van Den Hengel says.

AI RESOURCES

github.com/kjaisingh/high-school-guide-to-machine-learning
A guide for high school students on machine learning and artificial intelligence.

wired.com/tag/artificial-intelligence
Stay up to date with the field. Wired is one of the best platforms for anyone interested in tech.

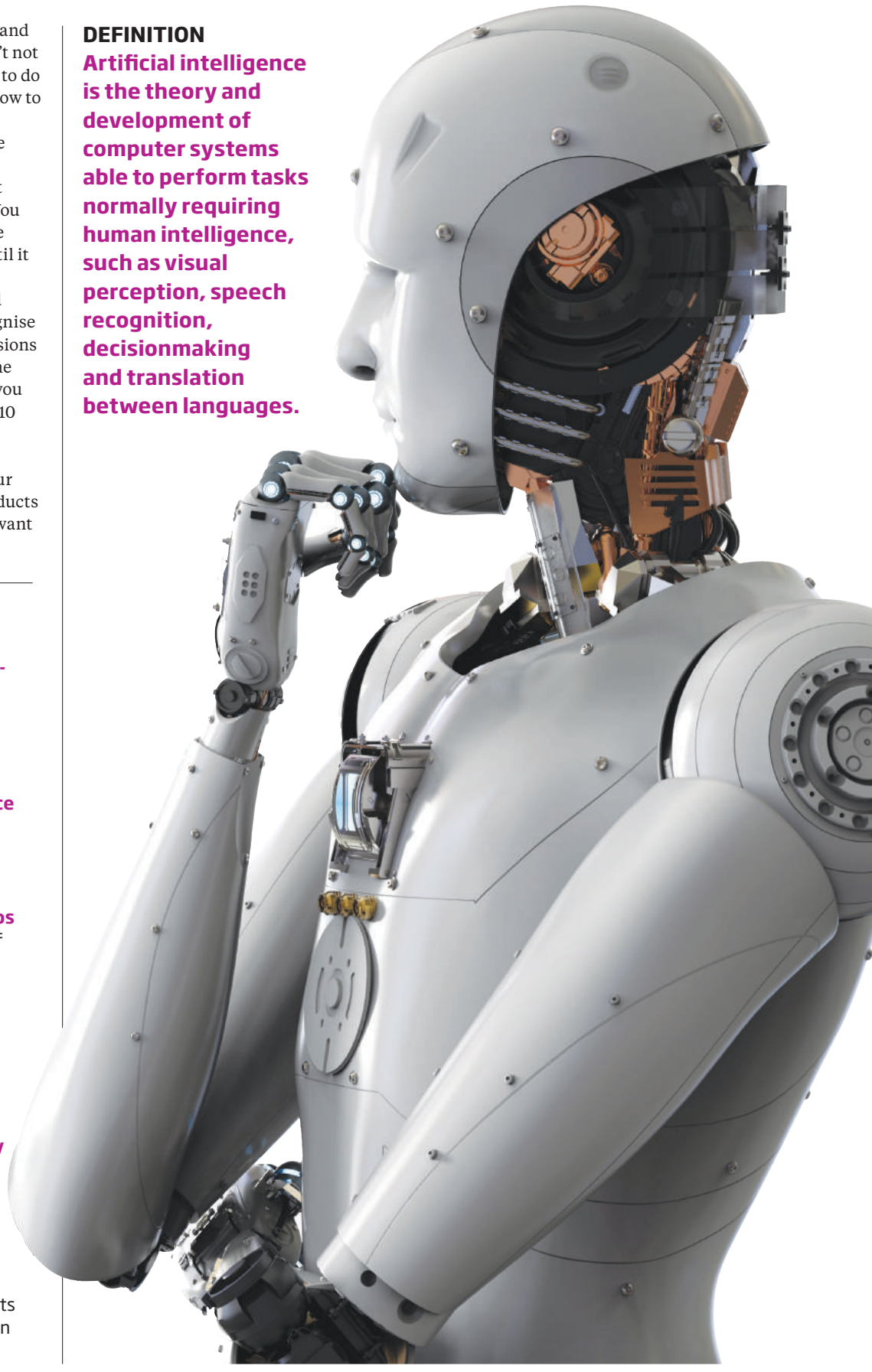
youtube.com/user/Maaaarth/videos
Interviews with pioneers in the field of artificial intelligence.

aitopics.org
The internet's largest collection of information about the research, the people and the applications of artificial intelligence.

csiro.au/en/Research/Technology
The CSIRO provides innovative information technology solutions that are helping to secure Australia's digital future.

itee.uq.edu.au
Fun learning activities for school students and teachers in robotics and information and communications technology.

DEFINITION
Artificial intelligence is the theory and development of computer systems able to perform tasks normally requiring human intelligence, such as visual perception, speech recognition, decisionmaking and translation between languages.



YOUR STEM FIT

YEAR 11/12 SUBJECTS

SCIENCE
- Biology
- Chemistry
- Earth and Environmental Science/Geology
- Nutrition
- Physics
- Scientific Studies

NUMERACY
- Accounting
- Business and Enterprise
- Economics
- General Maths
- Specialist Maths
- Tourism
- Food and Hospitality
- Math Methods
- Geography

CREATIVE
- Information Technology
- Design Technologies
- Art

LITERACY
- History
- English
- Engilsh Literature
- Philosophy
- Society and Culture

BODY
- Health
- Nutrition
- Outdoor Studies
- Psychology
- Child Studies
- Physical Education

DEGREE AREAS

- Science (Biology + Chemistry + Physics)
- Earth and Environmental Sciences
- Maths
- Engineering
- Computer Science
- Architecture
- Business
- Agriculture
- Medical
- Psychology

DEGREES

Science (Biology + Chemistry +Physics)
- Bachelor of Science (Honours) (Marine Biology and Aquaculture)
- Bachelor of Science (Biological Sciences)
- Bachelor of Science (EcoChemistry
- Bachelor of Science (Laser Physics and Technology)

Earth and Environmental Sciences
- Bachelor of Science (Ecotourism)
- Bachelor of Surveying and Spatial Sciences
- Bachelor of Natural Environment and Wildnerness Studies
- Bachelor of Science (Animal Behaviour)

Maths
- Bachelor of Mathematical Sciences

Engineering
- Bachelor of Engineering (Civil and Project Management) (Honours)
- Bachelor of Engineering (Mechanical) (Honours)
- Bachelor of Engineering (Civil and Infrastructure) (Honours)
- Bachelor of Engineering (Honours) (Mechatronics)

Computer Science
- Bachelor of Information Technology
- Bachelor of Computer Science (Professional) with a major in Cybersecurity
- Bachelor of Computer Science (Simulation and Serious Games)

Architecture
- Bachelor of Architectural Studies

Business
- Bachelor of Business (Global)
- Bachelor of Commerce
- Bachelor of Aviation and Piloting/ Bachelor of Business with a major in Finance
- Bachelor of Actuarial Studies

Agriculture
- Bachelor of Agricultural Science
- Bachelor of Viticulture and Oenology

Medical
- Bachelor of Pharmacy
- Bachelor of Science (Food Technology and Nutrition)
- Bachelor of Exercise Physiology
- Bachelor of Genetics

Psychology
- Bachelor of Social Work
- Bachelor of Behavioural Science (Psychology)
- Bachelor of Criminal Justice

CAREERS

Science/ Earth and Environmental Sciences
- Mammal keeper - Bristol Zoo
- Account manager - L'Oreal
- Engineering graduate scheme - textile manufacturer
- Publishing editor - Royal Society of Chemistry
- Environmental officer - airport
- Geotechnologist - engineering consultancy

Maths
- Forensic technology associate - Deloitte
- Actuary - PwC
- Trainee quantity surveyor - Bells
- Consumer insight manager - publishing company

Engineering
- Packaging engineer - pharmaceutical company
- Nuclear engineer - nuclear medicine research facility
- Electronics engineer - hospital
- Analyst - JP Morgan

Computer Science
- STEM promoter - higher education institution
- Cyberspace communication officer - defence force
- Technical solutions manager - IBM

Architecture
- Architectural technologist - estate agents
- Conservation specialist - construction company
- Planning officer - local council

Business
- Demand planner - construction company
- Community development support officer - charity
- Conference and events co-ordinator - hotel and spa chain
- Project control analyst - GE Oil & Gas

Agriculture
- Horticulture engagement officer - CSIRO
- Technical sales representative - Food Division SA
- Health, safety and environment adviser - mining company
- Agricultural technician - primary industries departments

Medical
- Sports development manager - rugby club
- Performance nutritionist elite sports - Dutch Olympic Committee
- Orthodontic dental nurse - dental hospital

Psychology
- Psychologist - autism specific intevention services - Autism Spectrum Australia (Aspect)
- Health and wellbeing consultant - Matchworks
- Website performance analyst - betting agency
- Social worker - local government

DREAMING OF

THE FUTURE

Enter the mind of Rising Sun Pictures co-founder and managing director **Tony Clark,** as he explores the past, present and future of visual special effects

WE LAUNCHED RSP in 1995 from a small office in Kensington with just four of us. We were tiny, but could see something big on the horizon. We believed telecommunications would soon become fast, accessible and cheap, and technology would eliminate distance as a factor for film studios when selecting effects studios to collaborate with on projects.

In our Kensington office, we had something rare at that time: a permanently connected 28.8kbps connection to the internet through Internode. It took an eternity to download anything, but as time went by, we moved first to 64kpbs, then 2mbps, working with Internode founder Simon Hackett to push the boundaries of price and performance.

Back then it took two weeks to ship our work to the US by courier, then get results back on film, so we also created a collection of tools to address the geographical distance from our principal market. One of them was our own broadband network, Cinenet, built with the assistance of the State Government, which went on to become something quite substantial and national. It addressed a gap in the market for well-priced, fast connectivity that was also holding other content creators back. Cinenet made it possible to send completed work directly to the client, turning a one-week courier trip into something that

could be done in an hour. Discussing aspects of visual work with a client half a world away was tricky – when you're in the same room, it's easier to see the same picture and point to the things you'd like to change. As a result, we created cineSync, which allowed filmmakers in various locations around the world to be looking at the same, high resolution, full frame rate image as the others in the session at the same time, no matter how far apart.

We were lucky with our early work and grew quickly, pushing into the office next door, then another one, then the upstairs and then the other side. Talented creative people came along and hung out with us to learn the tools and play in between our projects, and eventually joined the team in paid production roles. Many have since gone on to leading roles at RSP and in major companies around the world, with some starting their own businesses, and we're very proud of their successes.

The company has expanded tenfold since its inception and relocated twice to accommodate its growing staff numbers. First came the move from Kensington to Gouger St in the heart of the Adelaide CBD, then a move of just a few blocks to its current location on Pulteney St.

Over the years, we saw there was a gap between aspiring artists and experienced workforce professionals, so we partnered initially with Flinders University, and now the University of South Australia, to deliver training courses to bridge the gap and deliver production-ready artists. RSP's education program is unique in Australia and one of a few in the world that offers students the opportunity to learn the craft of visual effects from working professionals in a real-world production environment.

Courses are taught by RSP artists who've worked on such projects as *Thor: Ragnarok, Tomb Raider, The Hunger Games: Mockingjay Peter Rabbit, X-Men: Days of Future Past, Gravity* and *Game of Thrones*. *(Continued P29)*

TAFE SA Advanced Diploma - Screen and Media

The Computer Generated Imaging & Visual Effects Stream is for students who wish to work in the field of visual effects and 3D computer animation for TV and cinema. It is two courses rolled into one: TV production and 3D computer animation (incorporating visual effects). Students are taught the practical and theoretical aspects of the movie and television-making process so they understand where computer-generated imagery fits in the workflow of a production. Students get to use industry standard 2D and 3D software and broadcast-standard hardware.

FUTURE STUDY

Rising Sun Pictures offers Graduate Certificate programs in Compositing and Tracking and Dynamic Effects and Lighting, available to both local and global university students and advanced diploma graduates.

From 2019, Rising Sun Pictures will deliver the entire third year of UniSA's new VFX specialisation within the Bachelor of Media Arts degree.

The expanded partnership has been developed to meet what is expected to be a spike in demand for well-trained visual effects artists.

The Australian Government's recently expanded Post Production, Digital and Visual Effects Rebate is bringing more visual effects work to the country and, potentially, hundreds of well-paid jobs.

Rising Sun Pictures' education program is unique in Australia and one of a few in the world to offer students the opportunity to learn the craft of visual effects from working professionals in a real-world production environment.

Above: Before and after visual effects for *X-Men: Days of Future Past*. Above left: RSP created visual effects for *Thor: Ragnarok*, including a furious battle between the film's villain, Hela (Cate Blanchett), right, and an army of Valkyrie.

(Thor Ragnarok/Tony Clark/X-Men) Pictures: Rising Sun Pictures

DID YOU KNOW?

In *X-Men: Days of Future Past*, the character Quicksilver gleefully moves faster than the proverbial speeding bullet, making time appear to stand still. Under attack in a scene that takes place in the Pentagon kitchen, Quicksilver dodges bullets, moving them by repositioning them by hand. Instead, they shatter falling droplets of water, as pots, pans and boiling vegetables hang in mid-air. Each of these elements needed to be rendered in near microscopic detail, placed precisely within the geometry of the kitchen and choreographed to move and react realistically to lighting, other objects and characters. The scene, which runs for about two minutes, took a Rising Sun Pictures team of more than 60 people about six months to create.

CAREERS THROUGH CREATIVITY

For those seeking entry into the magical world of visual effects and filmmaking, a TAFE SA Advanced Diploma program of Screen and Media (specialising in CGI and Visual Effects) may give you the keys to the kingdom. Diploma students Eleisha Francis, 24, and Verity Colyer, 32, above, have cracked the code to find work with Adelaide's Rising Sun Pictures, which creates visual effects for feature film and television clients around the world, including films such as *Logan, X-Men: Apocalypse, Gravity, The Hunger Games* and *Game of Thrones*. After signing up for the two-year advanced diploma, both Francis and Colyer found their way into Rising Sun Pictures' production department. Initially seeking out a career in game design, Francis's stint at University of Adelaide then at TAFE SA doing the advanced diploma, led her to recognise the possibilities of CGI for a career. Both former students say the TAFE course was good grounding for the industry but it was the focus on the job outcomes they appreciated the most.

(From P27) Dozens of students who've trained in the program have gone on to land jobs at RSP or other visual effects companies around the world. This calendar year we'll take about 60 students and teach them the core aspects of what we do in a training course at Graduate Certificate level. It's incredibly effective, with a high proportion of students staying with us at Rising Sun Pictures, or finding roles at other facilities in Adelaide or interstate. The course closes the gap between what existing training institutions deliver and what we need as a production company. The people coming out of this course are production-ready and effective.

Being a visual effects artist is a great opportunity for creative people who are inclined towards anything on the spectrum between pure STEM and fine arts. Good VFX artists lie somewhere along the line between those two disciplines rather than at the extreme ends, as they need to have a bit of both in order to create images based on the ideas that filmmakers have in their heads.

So if you're on that line, absolutely enrol in these courses. It's a demanding industry to work in, and there will be extremely challenging times as projects near completion and you're working long hours.

Someone much smarter than me once said: "It's like jumping out of a plane and inventing a parachute on the way down." Much of what we do is like that – fortunately, not all of it. Our hiring process doesn't always look at qualifications – generally training reflects better skills so the person who spent all their spare time learning and making something really awesome is what we seek, and is in fact how many members of the original team came together.

Young people are extremely media literate, and now the tools are widely available. Production-quality software will run on the average home PC, and they're considerably faster than what we started with in 1995!

Download a copy of Autodesk Maya Learning Edition and get into that – it's online and free for non-commercial use. There are also learning editions of Nuke, Fusion, Blender and other tools that are similar to those we work with every day.

The next big thing? Cast your mind forward 10 or 15 years: your PlayStation will think faster than you do, and make entirely photoreal images. Advances in AI, machine learning and photoreal rendering in real time will combine to create sentient machines that will change storytelling altogether.

Instead of having a filmmaker present an unchangeable version of their vision, made with cameras and crew, you'll have an experience that is customised. It might be an expression of their idea, but melded with your tastes by your console."

Edited version of a speech by Tony Clark at the Australian Science Media Centre in 2018.

Watch making-of videos from Rising Sun pictures at rsp.com.au/projects

Chances are you've already seen the work of Rising Sun Pictures, which has contributed visual effects to more than 120 movies and TV series, including Tomb Raider, Thor: Ragnarok, Logan, and Game of Thrones, as well as the X-Men, Harry Potter and the Hunger Games series. Founded in 1995, Rising Sun Pictures, named after the Rising Sun Inn at Kensington, has grown to employ more than 200 staff.

GET WITH THE PROGRAMS

Software is not the be all and end all – it's a tool. First and foremost, you need to be an artist. Submerge yourself in what you love: drawing, painting, photography, sculpting, etc. However, it's practical to expose yourself to industry standard software packages used by VFX facilities around the world.

Nuke by The Foundry
Node based compositing system used extensively to integrate 2D and 3D elements. **foundry.com**

Maya by Autodesk
Used for modeling, animation, simulation, visual effects, lighting, rendering and matchmoving. **autodesk.com.au**

Houdini by SideFX
Powerful node based 3D software package responsible for creating some of today's award-winning digital effects. **sidefx.com**

3DEqualizer by Science-D-Visions
Professional 3D tracking and matchmoving software. **3dequalizer.com**

ANIMAL LOGIC

One of the world's leading independent creative digital studios, producing award-winning design, visual effects and animation. Teams in Sydney, Vancouver and LA.
Offers the Ready! Set! Go! work experience program and runs a Ready! work experience week at Sydney and Vancouver studios for senior high school students.
Set! training courses in Rotoscoping, Matchmove and Houdini for FX.
animallogic.com

TECHNICOLOR

Worldwide technology leader in the media and entertainment sector, at the forefront of digital innovation.
France-based. Offices in London, Paris, LA, Montreal, Toronto, Amsterdam, Chicago, NY, Vancouver, Bangalore and Shanghai.
Opening a new facility in Adelaide named Mill Film.
No details released on possible work experience programs, training programs or internships in Australia as yet.
technicolor.com

LEARNING HOW

TO PLAY THE GAME

THE EMPLOYEE

Nick Mower got his break into the world of games and animation through persistence and an industry incubator run by his now boss, Justin Wight, company director of Monkeystack studios in Adelaide.

"I did a TAFE course in game art and applied to the usual list of companies and got one interview and bombed it horribly," Mower, 29, says. "I discovered I was kind of relieved because I was actually terrified of going fulltime into the games industry because I didn't think I was ready. I applied for the Monkeystack incubator, which was a three-month industry simulation in a safe environment.

"Coming out of that I asked the guys' advice and they recommended I look into uni ... so I did a Bachelor of Media Arts at UniSA majoring in animation and went through the honours program as well. I felt I was more prepared but then couldn't find work for a year. I managed to get some tutoring jobs at TAFE then hooked up with Justin again who brought me in to (work) on game projects and I never left."

Monkeystack is a multi-disciplinary team of 36 people covering areas from animation, illustration and graphic design through to game design, user experience, programming and software development. Mower has now been working with the company for three years and is happy he persisted in gaining the requisite skill set.

"When I was a kid, the two fields I was obsessed with and couldn't pick between were video games – because I loved playing them and I loved coming up with the worlds and stories and stuff and I'd draw Mario levels and show them to people who weren't interested – and acting.

"I found that animation is a way to act without having to remember the lines. Animation was my way into the incubator but I never gave up my love of games. I love the challenge of ... creating this series of breadcrumbs to follow and then watch the player experience it. It's what they call emergent game play."

He says his choice of subjects at secondary school failed to support his career ambitions: "You're speaking to someone who didn't do any STEM subjects at school and now completely regrets it.

"I did the lowest level of maths and barely passed and that's really come back to haunt me. I dabble in programming and if you want to be a programmer you need a really strong core in maths.

"It is secondary to just pure maths. For me it was a failure of imagination because I'd look at the maths and say 'I don't see a use for this'."

THE BOSS

Justin Wight set up Monkeystack with several like-minded souls after a struggle to find work. He began his career with a Bachelor in Visual Communication, then an Advanced Diploma in Multimedia and set up his first business in 2002, only to have it fail in 2004. "The first business was the foundation of Monkeystack and a lot of clients came from that," he says.

Wight says the incubator that brought Nick Mower to his doors began as a three to four-month training program for post-graduate students or emerging talent. "They would work with us in the studio for two days a week, where we'd set them mock projects in their chosen field," he says. "It was all portfolio building for them." The incubator was set up to boost the skills of experience-poor job applicants. "(Recruiting has been) very challenging locally," he says. "People are not presenting with industry-relevant skills."

Wight says the incubator now runs on a more informal basis, designed around the needs of upcoming projects. He says the games industry can give you skills that are transferable to other industries. If you're a student looking for work: "Show me what you've done, show me you can do it. It's an incredibly competitive industry and they need to treat it as a lifestyle choice."

OTHER STUDIOS

ADELAIDE STUDIOS POST SOUND Sound post-production and re-recording, Adelaide.

ALT.VFX VFX and post-production company, Brisbane, Sydney, Melbourne and Los Angeles.

BIG BANG SOUND DESIGN Sound designers, editors and re-recording mixers, Sydney.

CUTTING EDGE Sound and picture post production and VFX, Brisbane, Sydney.

DELUXE VFX, post production and 2D-3D conversion services, Sydney, Los Angeles, New York.

FIN Boutique design and VFX, Sydney, Shanghai

KOJO filmmakers, VFX, Sydney, Melbourne, Adelaide, Perth.

LUMA VFX, Melbourne, Los Angeles.

METHOD STUDIOS A Deluxe subsidiary, VFX, AR/VR, Melbourne, Sydney, LA, NY, Vancouver, Pune (India).

NEW HOLLAND 2D-3D animation, Sydney.

PLASTIC WAX VFX, game and film animation, Sydney, LA.

RESIN Boutique VFX, Adelaide.

SLATEVFX VFX, Sydney.

SOUNDFIRM Sound and film post production, 2D-3D production, Melbourne, Sydney, Beijing.

SPECTRUM FILMS Sound and film post production, Sydney.

THE POST LOUNGE Post production, VFX, 2D-3D production, Brisbane, Melbourne.

TRACKDOWN Audio post production and music, Sydney.

(List source: ausfilm.com.au/why-film-in-australia/work-with-the-best/post-sound-music-vfx-production/)

The Difficult Bird Research Group studies Australia's most endangered birds, looking into ways to understand their ecology, conservation and seeks to identify ways to prevent extinction. **difficultbirds.com**

Dr Dejan Stojanovic. Picture: Australian National University

HEAD FOR HEIGHTS

SAVES PARROTS

Sugar gliders may be incredibly cute and only weigh about 120g but, until conservation biologist **Dr Dejan Stojanovic** came along, they were literally making a meal of Australia's endangered Swift parrots

STOJANOVIC'S PHD RESEARCH into the parrots discovered the night-time feeding habits of the marsupial gliders in Tasmania. "Before my PhD, no one had really looked at what happens in the parrots' nest, so it was my job to describe their breeding biology," he says.

"There was lots of tree climbing and the use of motion-sensitive cameras. We put them up and that's how we discovered what was killing and eating the birds."

Over subsequent years, working with colleagues at the Difficult Bird Research Group at the Australian National University and the National Environmental Science Program, Stojanovic trialled special nesting boxes for the parrots and developed a solar-powered door that closes at night, to keep the rampaging sugar gliders at bay.

"We trialled nest boxes by a crowd fund that we did. We held the record for the largest amount of money raised in the shortest amount of time for an environmental project in Australia – $70,000 in three days," he says.

"Then we broke our own record the next year by raising $113,000 in a week. Ever since then we've been tapping into crowd funding. People want to help but they don't know how, so it gives people an outlet to do something really practical."

The Swift parrots are described as difficult birds because they live in difficult-to-reach places – in the parrots' case, at the top of the tallest flowering plants in the world: eucalypts. "I went from zero to hero in tree climbing with Swift parrots," Stojanovic says.

"I'd never had to climb a tree and I had to learn in Tasmania. It was a very steep learning curve, in a literal sense. We've gone from next-to-no knowledge about the Swift parrot and what they need to breed to just, every year, chipping away and learning more and more. They've gone from never using nest boxes to totally using nest boxes to 'how do we use it to protect them?'."

He credits a good science teacher in Year 7 with setting him on his career path, along with a general love of animals: "I always found that animal behaviour stuff really cool. I wasn't a particular fan of high school but, when I got to university, I just loved it."

After a science degree at the University of Sydney, he researched different threatened bird species, leading to the ANU and the Threatened Species Research Hub run by the National Environmental Science Program.

"I never knew when I was young just how creative science is," Stojanovic says. "It is ... the only discipline where somebody like me can be walking around in the forest and think, 'Why is that happening?', and then spend time finding out."

THE NATIONAL ENVIRONMENTAL SCIENCE PROGRAM

NESP is a long-term commitment by the Australian Government to environment and climate research. NESP projects deliver collaborative, practical and applied research to inform decision making and on-the-ground action.

WHERE IS RESEARCH HAPPENING?

The $142.5 million National Environmental Science Program is being delivered through six research hubs:

Threatened Species Recovery Hub
Supporting the management of threats and improving recovery of threatened species
nespthreatenedspecies.edu.au

Clean Air and Urban Landscapes Hub
Supports environmental quality in urban areas
nespurban.edu.au

Earth Systems and Climate Change Hub
Furthering our understanding of the drivers of Australia's climate
nespclimate.com.au

Marine Biodiversity Hub
Researching Australian oceans and marine environments, including temperate coastal water quality and marine species
nespmarine.edu.au

Northern Australia Environmental Resources Hub
Supporting the sustainable development of our northern landscapes
nespnorthern.edu.au

Tropical Water Quality Hub
Researching coastal water quality and coastal management focused on the Great Barrier Reef and other tropical waters
nesptropical.edu.au

DID YOU KNOW?

The Swift parrot (Lathamus discolor) breeds in Tasmania and migrates north to south-eastern Australia from Griffith-Warialda in NSW and west to Adelaide in the winter. It is related to the rosella, with the feeding habits of a lorikeet. It is the only member in the genus Lathamus.

FOR THE LOVE OF

LIVING CREATURES

A fascination with the natural environment has led **Dr Rebecca McIntosh** around the world and back to Oz for some citizen science with fur seals

RESEARCH SCIENTIST Dr Rebecca McIntosh has a lifelong fascination for living creatures – something she gives thanks for to both her mum and Jacques Cousteau. "My mum definitely taught me a strong connection and love with animals and natural things, and a deep respect," she says. "I can remember with my brother when I was little, we wanted to know about cicadas, so we caught a heap of them and wrote numbers on their backs. We didn't know we were doing a capture-mark-release process... but we numbered them and let them go and they didn't come back again. It was part of my curiosity about the world."

My mum definitely taught me a strong connection and love with animals and natural things and a deep respect

Then came Cousteau, a French conservationist and filmmaker who gave much of the world in the 20th century their first real understanding of life beneath the waves.

"Similar to the effect David Attenborough has had on generations, I was strongly affected by Jacques Cousteau and seeing those amazing documentaries growing up," McIntosh says.

"My family ... didn't have that ocean side of things in our lifestyle. I just loved anything to do with the ocean and I made my parents sign a form so I could go and get my diving ticket when I was 16. The marine environment really pushed my buttons."

At school, McIntosh studied biology – her true love – and general sciences but added in humanities subjects: the classics, art and history. "I just loved learning. I think the best thing you can have is that love of learning, and that's what gets you through the hurdles of where you want to go," she says.

She chose Melbourne University because it had a strong dive club and a marine biology study stream, completing a double science degree in biology and zoology. "I realised fairly early on that a lot of the stuff you learn can apply to any system – it's just the techniques. You need to focus on how you think more than the animals you're working on," she says.

After three years working and volunteering around the world, including a seven-month stint with a marine biology team in the Galapagos Islands, she chose to do her PhD on the Australian sea lion, one of the world's many endangered species. McIntosh, now 42, took up her latest project after discovering the delights of drone technology – something she could use to study animals without disturbing them in their natural habitat.

"When drones came on the scene I thought, 'I need to get into this' because I could see so many applications for it," she says. "What a cool way to get people who don't get to see the stuff I get to see. What an amazing thing to be able to bring people into that space and help with the work and for them to feel a connection."

Working with Phillip Island Nature Parks, the Telematics Trust and the Penguin Foundation, she has set up the Seal Spotter program, which uses drones and citizen science to count Australian fur seals inhabiting Phillip Island. "There can be tens of thousands of animals out there and we've never been able to count them because, as you approach, they'll run into the water," McIntosh says. "With the drone we can take photos and then we can get people to count them with us.

"We are inviting people to look at seals in a way they've never been able to do before."

The data, which counts seals in different age groups and also measures the amount of harmful marine debris present, such as fishing line and plastic bags, is used to understand the health of the marine system. So far, the 326 registered citizens have counted many thousands of seals and noted a much larger amount of debris affecting them than previously thought.

McIntosh advises students to get a handle on the secondary school subjects needed to study zoology and marine biology at uni, but to balance that with subjects that give them another way of thinking about the world. Ultimately she says, if you have a dream to be a scientist, pursue it in whatever way you can. "If you don't do really well at the end of Year 12, it won't be the end of the world," she says. "You can go out into the world and get some experience at other things and go back to uni later. Get some volunteering done and see if you like marine science."

She says a science degree provides many skills making you employable across industry, consulting, academic and research-based tasks.

INSET: Dr Rebecca McIntosh Picture: Phillip Island Nature Park

DID YOU KNOW?

Jacques Cousteau (1910-1997) was a French naval officer, explorer, conservationist, filmmaker, innovator, scientist, photographer, author and researcher who studied the sea. He is credited with co-developing the Aqua Lung with engineer Émile Gagnan in the 1940s, the first open-circuit, self-contained underwater breathing apparatus (SCUBA) to achieve commercial success. Cousteau wrote books and made a huge number of films and documentaries that informed generations of young people about life in the oceans and promoted the importance of conserving the natural environment.

MARINE BIOLOGY RESOURCES

natureparksresearch.com.au/sealSpotter/
SealSpotter allows anyone with a computer to help with the management and protection of our oceans by counting seals in images captured with a UAV (drone).

penguinfoundation.org.au
The Penguin Foundation raises funds to protect and enhance Phillip Island's natural environment through research, conservation and education programs.

coursesearch.unimelb.edu.au/majors/24-marine-biology
Courses on marine biology at Melbourne University.

csiro.au/en/Research/Animals-and-plants/Wildlife
The CSIRO's research projects in the field of marine biology.

aims.gov.au
The Australian Institute of Marine Science (AIMS) is Australia's tropical marine research agency.

A series of photos taken by a drone is available to view on the SealSpotter website and anyone with a laptop and internet connection is able to count the number of seals in each photo and submit their total. The average count from each photo is used to estimate the size of the colony. Visit: natureparksresearch.com.au/sealSpotter

Dr Peter Thomas-Hall. Picture: Marie Roman/Australian Institute of Marine Science

THE WINNER TAKES THE CROWN

THE CROWN-OF-THORNS starfish is much like the seemingly invincible creature featured in the movie *Alien*. The starfish has sharp, poisonous spines that kill most fish. It can throw its stomach on to a bed of coral and eat the reef for dinner and, if it's cut in two, it can regenerate into two starfish. It also produces more eggs than any other known animal: 50 million at a time.

It's a formidable enemy and one that has destroyed up to a quarter of the Great Barrier Reef in just the past 30 years.

One scientist is part of a team fighting back against the invader by finding a way to deploy the one living thing that can kill it – the world's largest sea snail, the Giant Triton or Triton's Trumpet. At the Australian Institute of Marine Science in Queensland, Dr Peter Thomas-Hall is a chemist working on a breeding program to reproduce the Triton, which is immune to the starfish toxins and actively hunts them down. "It's a keystone predator and the smell from the Triton freaks out the crown-of-thorns starfish – it's a very potent repellent," he says. "We've known for years that Tritons eat the starfish but it's new that the smell from the Triton freaks them out. I've been on this project for about four-and-a-half years as a chemist."

The breeding program is necessary because the Triton was fished almost out of existence by pearlers and collectors looking for the rare and valuable shells. "They've been protected in Australian waters since the 1970s. (But) from 1870 to 1970, most of the world's pearls came from Australia from a massive pearl lugger fleet," Thomas-Hall says. "They'd go diving for pearls and as a by-catch they'd also collect the Triton's Trumpet shell. (As a result) it took us two-and-a-half years to find just eight shells on the Great Barrier Reef."

Those few Tritons are now in specially designed tanks and laying eggs but, so far, the scientists have only been able to keep the larvae alive for 90 days. "We think they'll probably need to be in the larval form for about a year," he says. "They are a very challenging species to breed – a number of groups have tried but failed."

Thomas-Hall is no stranger to perseverance in the face of tall odds. Although he loved science and was fixed on studying chemistry at university, his natural talents did not run to study. "I was actually terrible at studying but I was good with my hands and making things and problem solving, so I had to work very hard to get passes," he says. "I failed high school and had to do TAFE to get into university. In first-year uni, I failed six of my eight subjects but I kept going and I kept at it and managed to get through the degree."

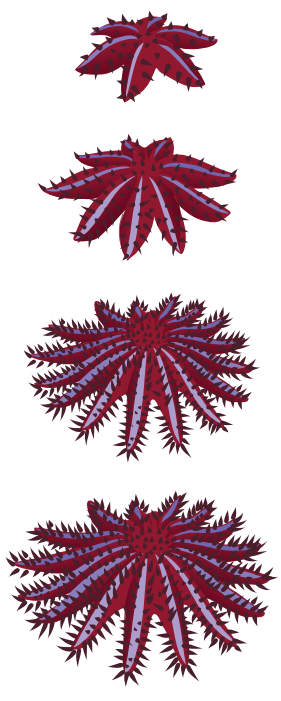
His persistence and broad range of skills won him a job at AIMS. "I love working in science," he says. "A good portion of my job is fixing things. A lot of science students who come here are blown away by how much hands-on you need to do in order to get experiments to work."

The work goes on for Thomas-Hall, who hopes to one day rid the reef of the crown-of-thorns scourge by returning its exploding numbers to regular levels.

STAR-STRUCK

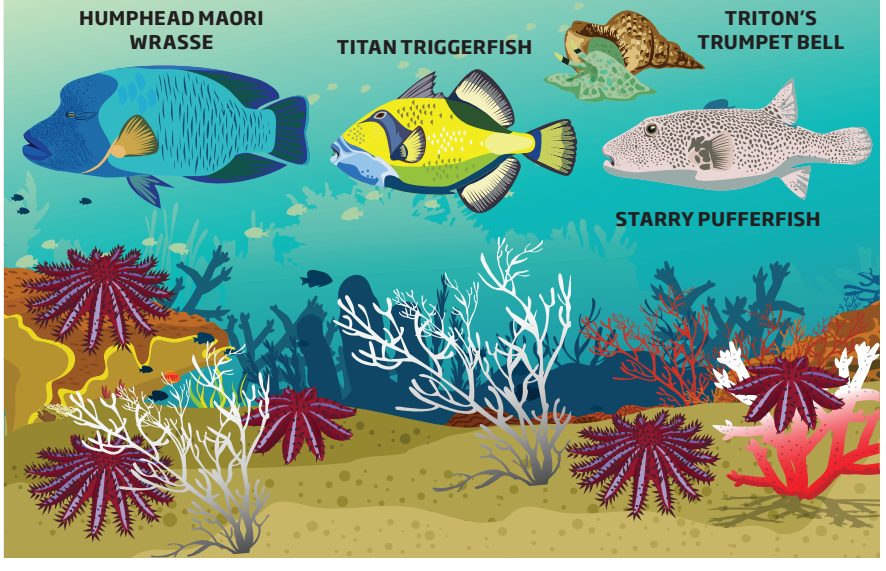
She has up to 21 arms, more than 600 ovaries and hundreds of 4cm-long toxin-tipped thorns. She grows to 80cm across, eats 10sqm of coral a year and can produce up to 50 million eggs a year. An adult female Crown-of-thorns starfish (COTS) is a formidable predator. She belongs on the reef. She's not an introduced pest. COTS are natural predators of the coral on the Great Barrier Reef and on coral reefs from the Red Sea to the west coast of the Americas. Her larvae spend 14-30 days as plankton before they settle and change into five-armed juvenile starfish. Over the next six months to a year, they change again into the adult form and begin consuming corals. Within two years, they can be sexually mature. Adult starfish have few natural predators and little is known about the impact of these predators on outbreaks. Predators of adult COTS include the Giant Triton snail, the humphead Maori wrasse, starry pufferfish and titan triggerfish. Predators of juvenile starfish include shrimp, crabs and polychaete worms. There are fewer COTS outbreaks on reefs in marine-protected areas, perhaps because more of the juveniles get eaten. *Source: AIMS*

LIFE CYCLE



CROWN-OF-THORNS STARFISH PREDATORS

Over-fishing has significantly reduced the number of these animals (below) that prey on the crown-of-thorns starfish. In the absence of predators the reef can be killed off by outbreaks of the starfish.



Dr Sarah Cohen-Woods is head of the Behavioural Genomic and Environmental Mechanisms Lab at Flinders University

HELPING BUILD BETTER

BODIES

Research by **Dr Sarah Cohen-Woods**, who collaborates with scientists around the world, is revealing how our genes make us tick

THERE'S A LONGSTANDING debate about the importance of nature versus nurture when it comes to why we are the way we are. Epigenetics seeks to cast this debate in a new light: that how our genes are "expressed" is not dictated by DNA alone, says the head of the Behavioural Genomic and Environmental Mechanisms Lab at Flinders University, Dr Sarah Cohen-Woods.

Specifically, Cohen-Woods is interested in the epigenetics of behaviour and how environmental factors can affect our risk for certain psychological problems.

"I was clear that neither nature, nor nurture, definitively explained psychological disorders and that these factors work together to impact our behaviour and psychological outcomes," she says. "This is an emerging field, and the science is new, however there is increasing evidence that stress, diet and exercise exposures all can influence our gene expression beyond our DNA code."

The most studied epigenetic process is methylation. Not as incomprehensible as it might sound, methylation refers to a process that effectively switches our genes on and off, without changing our DNA code. This has been recognised as an important factor in disease for some time, particularly in cancer and cancerous cell growth. However, more recently, the potential significance of epigenetics to behaviour and psychology has become apparent.

"Differences can be observed in epigenetic factors such as DNA methylation in psychological conditions, such as depression, bipolar disorder and schizophrenia," Cohen-Woods says. "Although we know that these conditions have a strong genetic component – up to 80 per cent heritable in the case of bipolar disorder – we also know that the environment is also an important factor – up to 60 per cent in depression. It is rapidly becoming apparent that environmental factors can influence epigenetic characterisation, which may have the potential to influence our behaviour."

Studying this has already led Cohen-

Woods, who studied for a science degree with honours followed by a masters and PhD in social, genetic and developmental psychiatry in London, to some important discoveries.

These include contributing to the identification of genetic risk factors in depression, anorexia nervosa and psychosis. "This has been a mammoth task requiring collaboration across the world with hundreds of scientists," Cohen-Woods says.

"This is extremely exciting as we have needed huge numbers of people in our studies to identify these risk factors – up to 350,000 people. My research really does require teamwork and a willingness to work together to achieve our aim to help people with these psychological conditions.

"Recently my research has also identified a genetic risk factor that only increases risk to depression in individuals with a history of childhood maltreatment. This is very exciting as it is within the immune and inflammation system and may demonstrate new pathways that we can target in subgroups of people with depression. We have also demonstrated that short-term physical interventions, such as yoga, can alter your epigenetic profile in cells in your blood, although this was not related to psychological outcomes directly. This is important as it demonstrates how quickly these epigenetic changes can occur."

During her Bachelor of Science with honours in psychology, Cohen-Woods chose subjects with a strong biological basis, as well as social and statistical methods, but says the students she works with in the field come from a wide variety of backgrounds. Many choose to diversify if they come from a psychological background.

"My psychology students undertake extra online courses to get up to speed on bioinformatic – computer programming and statistical analysis – and genetic methods," she says. "If you already know this is something that interests you, and why wouldn't it, I encourage you to consider chemistry and biology. At the very least science topics and, if you can, statistics and/or maths topics, and then whatever other topics are of interest to you."

After graduation, job opportunities are broad. "There are research opportunities – it is currently a very hot topic – industry opportunities like working for research companies such as Pfizer, sales opportunities working for companies that sell lab products, and teaching opportunities," Cohen-Woods says.

"Future research will focus increasingly on how our environment can influence our epigenetic factors and in turn how this can impact disease outcomes. "People that work in this area have to be willing to learn new methods and techniques rapidly as the field is always changing, and it is important that they work in a highly disciplinary manner, for example, with multiple groups of researchers from different areas.

"Science is a wonderful thing and I will always encourage students to engage early on. Having said that, if they haven't yet, it isn't too late to enter this field if you are keen and enthusiastic."

BEHAVIOURAL GENOMIC AND ENVIRONMENTAL MECHANISMS LAB

The laboratory investigates genomic, epigenomic, and environmental factors contributing to mental health outcomes, and fertility. Looking across the lifespan from baby to geriatric, the three broad research streams are genomics in mental health and behaviour, environmental mechanisms and epigenomics in mental health, behaviour, and fertility, and school uniform equity and impact on child wellbeing.

A DAY IN THE LIFE OF AN EPIDEMIOLOGIST

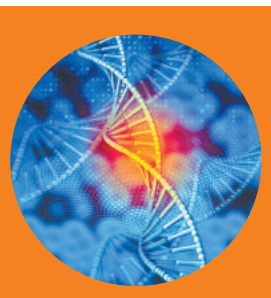
EVER WATCHED ONE of those movies where a tiny town is infected with a dreadful disease – people dying gruesomely everywhere – and the government sends in a team of white-suited scientists to work out what the disease is, where it started and how to stop it? Those people are the epidemiologists.

Epidemiology studies the incidence, distribution and possible control of diseases and other factors relating to health. And having an interest in maths helps. Mary Barnes is a biostatistics lecturer – she teaches students the application of statistics to biological and medical sciences – at the Flinders Centre for Epidemiology and Biostatistics.

She says there is a global shortage of epidemiologists, with a predicted increasing demand. "In 2012, I co-developed an iPhone app that helps surgeons predict patient outcomes for a specific aneurysm repair," Barnes says.

"It is a risk assessment model developed to assist with the decision-making process that takes place between a surgeon and a patient considering endovascular repair for an abdominal aortic aneurysm. Surgeons use this model to inform their patients about the likelihood of an adverse outcome following surgery, based on selected pre-operative patient variables."

As well as teaching the epidemiologists of tomorrow, she is working on projects, from advising on readjusting the sampling strategy for the health star rating audit to publishing a journal article on the correlation between the width of ACL and diameter of hamstring tendons in knee MRI scans. "It is a very exciting area to work in," Barnes says. "Ideally, I'd recommend studying mathematics or any statistics subjects at school. Also choosing science subjects such as biology and chemistry would be helpful for an epidemiological career."



EPIGENETICS

Epigenetics affects how genes are read by cells and, subsequently, how they produce proteins. Here are a few important points about epigenetics:

Epigenetics controls genes
Certain circumstances in life can cause genes to be silenced or expressed over time. In other words, they can be turned off (becoming dormant) or turned on (becoming active).

Epigenetics is everywhere
What you eat, where you live, who you interact with, when you sleep, how you exercise, even ageing – all of these can eventually cause chemical modifications around the genes that will turn those genes on or off over time. Additionally, in certain diseases, such as cancer or Alzheimer's, various genes will be switched into the opposite state, away from the normal/healthy state.

Epigenetics makes us unique
Even though we are all human, why do some of us have blonde hair or darker skin? Why do some of us hate the taste of mushrooms or eggplant? Why are some of us more sociable than others? The different combinations of genes that are turned on or off is what makes each one of us unique. Furthermore, there have been indications that some epigenetic changes can be inherited.

Epigenetics is reversible
With 20,000-plus genes, what will be the result of the different combinations of genes being turned on or off? The possible arrangements are enormous! But if we could map every single cause and effect of the different combinations, and if we could reverse the gene's state to keep the good while eliminating the bad ... then we could theoretically cure cancer, slow ageing, stop obesity and so much more.

Source: whatisepigenetics.com

A CAREER SET IN

MOTION

Dr Sophie Calabretto is developing the maths that will help build more efficient aircraft and develop the next generation of global climate models

SOPHIE CALABRETTO IS happy to stir the pot when it comes to mathematics – as a fluid mechanist, it's her job.

She's also passionate about defragging the dull, dusty reputation often associated with the field and opening up a world of career opportunities for young maths students.

"I obviously really enjoy what I do but people sometimes discount maths because they don't think they can make a career out of it, necessarily," she says.

"But the better you are in maths and statistics the better you are at any kind of science and, in fact, in any job role ever, because you are learning all these skills that you don't realise you're learning – like critical and analytical thinking, problem solving and even communication."

Calabretto says her reasoning is borne out in studies that show the longer you study maths and statistics at school, the more employable you become across every sector.

I've worked in biological maths and fluid mechanics. But with any problem you want to solve or any area you are interested in, you can do that mathematically

"But, as far as maths goes, you've got such a breadth of things you can do," she says. "I've worked in biological maths and fluid mechanics. But with any problem you want to solve or any area you are interested in, you can do that mathematically."

Calabretto has never been short on ambition: "Originally I wanted to be a marine biologist or an Olympic sprinter but, by the time I got to the end of high school, I wanted to be an astrophysicist.

"Until picking subjects in Year 11, I probably did an equal amount of arts and sciences. But, career wise, I'd always been leaning a bit more towards science.

"I've always been a fan of doing what you're interested in, not necessarily what you think is the best decision. I quite enjoyed physics by the end of high school and I thought space was really cool, so that's where the astrophysics came in." It was while studying a double degree in science and arts at the University of Adelaide, working through the maths subjects she needed to do physics, that she truly fell for the subject.

"In honours, I worked on a project in a field called dynamical systems, looking at the firing of the neuronal synapses – a biological-maths kind of project, which I really enjoyed."

For her PhD, her supervisor convinced her to work with him in his field of fluid mechanics: "I kind of just fell in love with it from there."

Calabretto says she likes maths because it is a "rigorous" subject and is the backbone of all science. "You start from the bottom and you work your way up. You've got these mathematical equations that describe things, and you use them and get information out of them and you solve problems," she says.

As fewer students take up her beloved profession, she now visits schools to reignite the flame in students by proving how fundamental maths is to everyday life and how many careers it can open up to them: "I tell them, what I want is for you to do as much maths and statistics as possible, and to the highest level possible, because it gives people the best chance to succeed."

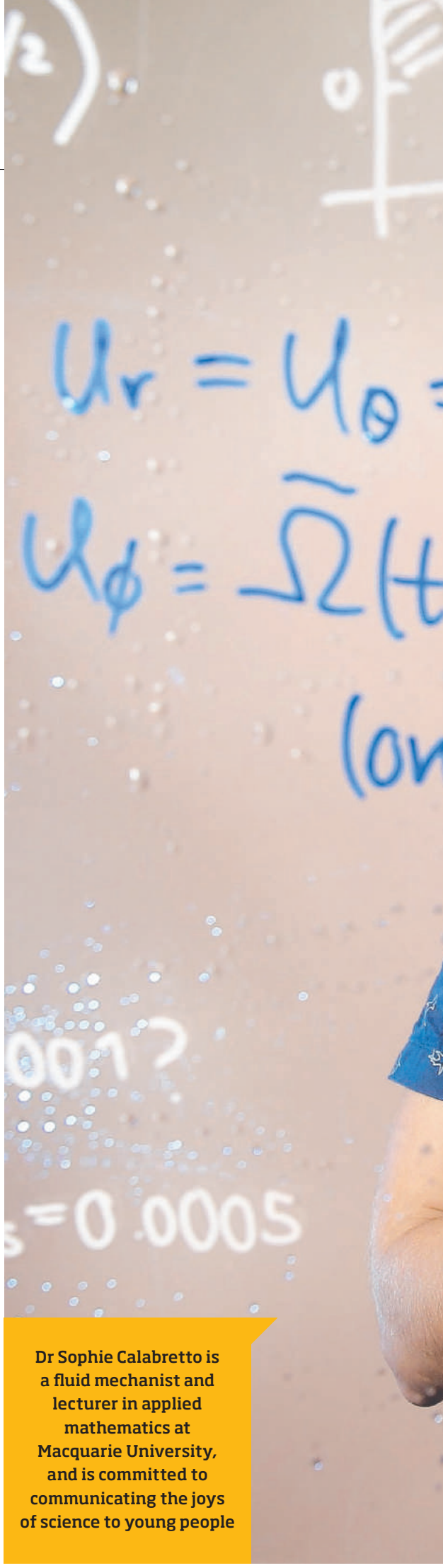
She particularly encourages young women to pursue the field to even out the gender imbalance.

"When you think of a mathematician you don't necessarily think of a woman," she says. "So one of the things we try to do is change the perception and have good role models and have the students understand that there is a community of female mathematicians.

"It's not some weird old-boys' club anymore. If you're interested in it, just do it."

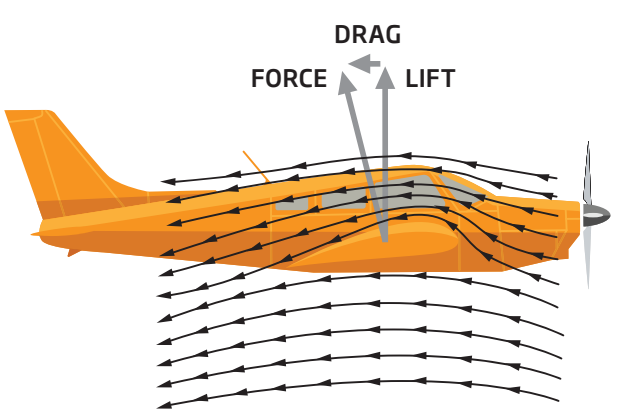
CAREERS USING MATHS

- Air Traffic Controller
- Geologist
- Animator
- Architect
- Astronaut
- Market Research Analyst
- Biologist
- Mathematical Biophysicist
- Cartographer
- Mechanical Engineer
- Chemical Engineer
- National Security Analyst
- Chemist
- Climatologist
- Computational Biologist
- Physician/Nurse
- Computer Scientist
- Cryptanalyst
- Economist
- Financial Market Analyst/ Stockbroker
- Electrical Engineer
- Statistician
- Forensic Analyst
- Urban Planner



Dr Sophie Calabretto is a fluid mechanist and lecturer in applied mathematics at Macquarie University, and is committed to communicating the joys of science to young people

APPLICATIONS OF FLUID DYNAMICS



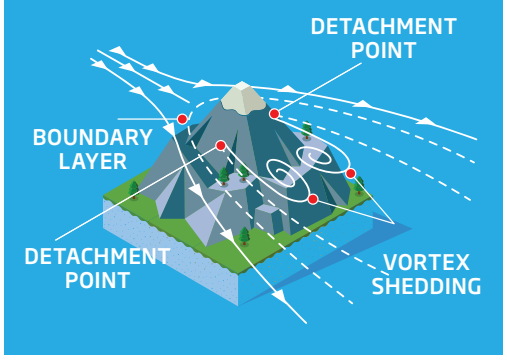
Streamline flow around a moving airraft wing
LIFT is the upward force on the wing from the air.
DRAG is the resistance. The lift depends on the speed of the aircraft, the area of the wing, its curvature, and the angle between the wing and the horizontal.

FLUID DYNAMICS

Working in fluid dynamics, Sophie Calabretto gets to examine what happens with large bodies of rotating fluid, among other things. "What we're interested in is why you have very nicely behaved flow ... and why that becomes a bit unstable and transitions into a state of turbulence," she says. Working out why the turbulence occurs translates into everyday life in many ways, including looking at turbulent air over the wings of a plane, making the aircraft use more fuel to stay aloft. "We are looking at the fundamental behaviour of what makes fluid behave badly because it has applications everywhere else, so then people can go and design better aeroplanes or whatever," Calabretto says. In climate science "you'll get these big swirling ocean eddies out in the middle of oceans and we are interested in finding them, because it's though that the way these eddies behave has a huge impact on the large currents in the ocean". "We know all the currents are linked to climate, which turns into weather, so ... you get a better idea of their impact on climate and climate modelling," she says.

VORTEX STREETS

This phenomenon occurs when fluid flows around an obstacle, such as wind around a mountain peak. Any substance that flows, including air, is considered a fluid. Whenever moving fluid is forced to flow around an obstacle, we encounter an event known as boundary-layer separation. A boundary layer is a thin layer of fluid that forms around an obstacle as it moves through a fluid, or as a fluid moves past the obstacle. The mountain acts like a windbreak so the air moving past it travels faster than the air behind it, causing a low-pressure area to form behind the mountain. If the wind is fast enough, the air in the boundary layer is forced to detach from the surface.



Farmer Jonathon Dyer. Picture: Zoe Phillips

Grain farmer Jonathan Dyer of Kaniva, Victoria, is an information technology graduate from the University of Ballarat (now Federation University Australia)

PROBLEM SOLVING

Finding good graduates with the skills to excel in this area of research is a challenge, says CSIRO Agriculture and Food deputy director of science Michael Robertson. He sees a disconnect between demand and supply, with the vast majority of postdoctoral researchers employed in this area of research at CSIRO coming from overseas, at least in recent years. That is partly a consequence of agriculture becoming a more globalised pursuit, backed by big industry and serviced by web-based support services that may be based offshore, but also because our universities are failing to adapt their courses to the needs of modern farmers. "I believe university courses being offered in ag science have hardly changed since I left university," he says. "So there's been, I think, a real failure in the system to equip our ag science graduates in data science, in the use of digital technology, in knowledge science, so how you find and use different knowledge sources to solve a problem."

A RIPE AND READY HARVEST

The age-old profession that supported the expansion of human civilisation and enabled the industrial revolution is being transformed by technology

RIPE AND READY for harvest, golden wheat sways in the breeze. The air is fresh, the sky is clear, life on the land seems simple. But all is not as it seems. Behind the scenes, automated sensors are monitoring the weather, passing satellites are keeping watch and all manner of machines are gathering data as they roll across the landscape. Technology is driving change, giving modern farmers access to information their forefathers barely dreamt of.

Grain farmer Jonathan Dyer of Kaniva, Victoria, is alert to the opportunity. As an information technology graduate from the University of Ballarat (now Federation University Australia), he knows more than most about the potential to harness data for better decisionmaking. But he longs for better tools and resources, because more information is meaningless without the skills to interpret the information and put it to good use.

"No one becomes a farmer because they want to sit in an office and do statistics and analysis, look at spreadsheets and maps and these sorts of things, but actually that might be what a farmer needs to do, going forward," Dyer says. "These technologies give a deeper, more nuanced understanding of what's going on in our farms – especially for me on a grain farm at a large scale, you can understand in more detail what's happening in the paddocks – but the skills we need to use these technologies are quite different to what farmers are used to."

As a Nuffield Australia Farming Scholar (2015), Dyer travelled overseas, exploring ways to use big data to improve farm practice and profitability. The scholarships provide $30,000 for up to 16 weeks overseas travel over 18 months, promoting leadership and innovative practice in agriculture. Dyer has just installed three weather stations, which are "always online collecting our weather data", including wind, rainfall, temperature and humidity. It's about matching "inputs" such as fertiliser, lime and gypsum to the needs of the crop on a given patch of soil, to save money and the environment.

While every plant in a field of wheat may look alike to the untrained eye, yield mapping reveals vast differences. "Every harvester made in last 10 to 15 years has yield mapping capabilities; it collects data about the yield of the crops that you're harvesting as you're going along," he says.

"We've had this ability for a long time but we haven't been able to use it very well, because we haven't had the support infrastructure around it – having advisers that understand how to do mapping and then software that can convert a yield map into a fertiliser application map for the coming year. It's all coming ... but that's why we need good graduates, to make us better tools and new products, to make these things easier to understand."

NUFFIELD AUSTRALIA FARMING SCHOLARS

Nuffield Australia awards scholarships each year to farmers with the objective of increasing farming knowledge management skills and techniques generally. These scholarships give the chance to study farming practices in New Zealand, Europe, Asia and the Americas.

Elders agronomists Rylie Cherrey and Diana George. Picture: Michael Grant

DOING FARMERS' DETECTIVE WORK

PLANT DOCTOR DIANA GEORGE, 26, helps farmers make the most of their crops and pastures.

"If there's anything going wrong, I try to get to the bottom of it," she says. "I look at soil tests, look for any diseases or pests and things like that, to come up with a solution."

The Elders agronomist is a recent graduate of the University of New England with a Bachelor of Agriculture, majoring in general agricultural production.

She finished the course in 2014 and started "madly applying for all sorts of jobs".

"Then a friend of mine sent me a screen shot on Twitter of Elders advertising the first round of their Graduate Agronomy Program," George says. "I applied and was one of the three graduates they put on in 2015. It's been a fabulous experience; I highly recommend it."

She spent the first six months at Elders Gatton, about 100km west of Brisbane, increasing her knowledge of horticulture, before moving northwest to Elders Toowoomba for 18 months in broadacre agronomy. In April 2017, she started work at Elders Ballarat, supporting farmers across the region from Ballarat to Mortlake and Ararat.

Along the way George has felt "extremely thankful" to have such a strong grounding in science through her degree. "To understand how plants work and how the soil works you have to go back to the basics of biology and chemistry," she says.

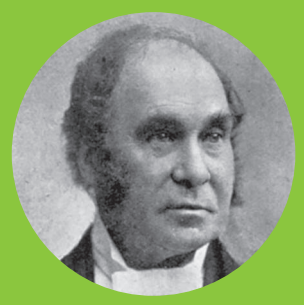
Agriculture is extremely diverse and it can take you anywhere. If you're passionate about it there's definitely a lot of opportunities.

"I'm still learning in my role; I haven't stopped learning for the last three years since I left university, but being able to fall back on bits and pieces I did at university with science has really helped me. And maths is a pretty integral part of life, I think."

Growing up on a mixed farming property at Forest Grove, Nevertire in central western NSW helped, too, she says.

DID YOU KNOW?

Elders employs more than 130 agronomists across the country in all crop segments. The Elders Graduate Agronomy Program covers various aspects of broadacre cropping and horticulture over 18 months. The Thomas Elders Institute was recently established to bring scientific findings to the farm gate and commercialise findings. While still in its infancy, the institute is an example of how the industry is increasingly focused on precision agriculture.



FUTURE FARMERS

SMART farmers are using science and tech to support decision making at every level of the business, including:

CHOICE of varieties of crops or pasture, or breeds of animals.
CHOICE of chemical inputs like pesticides, herbicides, fertilisers or medicines.
WHAT to do when, from preparing the soil, sowing the seed through to harvest
WHERE to send produce, assessing different markets and potential prices.

They may take into account:

WEATHER and climate forecasts.
INFO from satellites and sensor soil types, moisture levels and pH.
PREDICTIONS of crop yield or feed availability.
YIELD monitors and maps at harvest, recording variation across the farm
APPS for everything, even checking spot prices and selling products online.

Emerging technology for future farmers includes:

NEW crop varieties that may be more drought-tolerant, pest-resistant, high-yield or more nutritious.
GPS trackers/sensors on livestock that tell how much they're eating, if they're falling ill or not, even whether they are giving birth.
SOURCE: CSIRO Agriculture and Food deputy director of science Michael Robertson

FROM OUT OF SHOEBOX TO YOU

NEW TECHNOLOGY is poised to transform farming by helping to solve Australia's rural connectivity woes.

Today, more than 61 per cent of Australia's land mass is owned by farmers and the implications of operating in remote, often harsh conditions throw up many challenges. Adelaide-based next-generation connectivity business Fleet Space Technologies is working to solve these challenges – from space.

Fleet will launch a constellation of nanosatellites to create a scalable, global network to cost-effectively provide connectivity to on-farm sensors, enabling farmers to rely on accurate near real-time data to make important decisions.

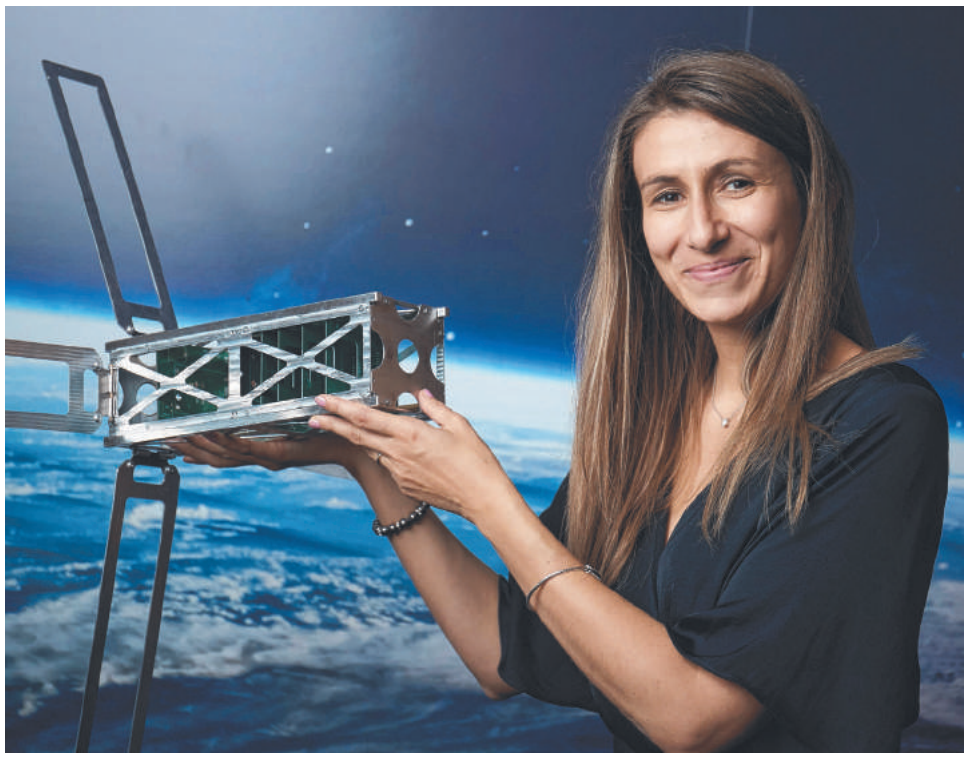
Fleet chief executive Flavia Tata Nardini says Australian farmers must be receptive to new technologies or risk falling behind in the competitive global market.

"The untapped potential of the Internet of Things (IoT) devices in transforming the global agriculture industry at a macro and micro level is astonishing," Tata Nardini says. "But the remote nature of farming means that, right now, there's a severe limitation in the number of devices that can connect to the internet.

"Imagine the possibilities of IoT for Australian farmers. Producers will now be able to collect precise data to drive environmentally sustainable practices with novel sensing techniques and smart applications."

Fleet recently launched a fully integrated satellite-enabled LoRaWAN solution The Portal, in trials across Australia.

"We must adopt technology that allows Australian farmers to work more efficiently and gain a competitive edge," she says.



NEW WAYS TO FEED

THE FLOCK

Dr Sofie De Meyer is CEO and founder of MALDI ID, Postdoctoral Fellow at Murdoch University in Perth and associate fellow at Ghent University in Belgium

SHEEP FARMERS WHO struggle to feed their flocks through harsh Australian summers can look forward to greener pastures thanks to Murdoch University research.

Agricultural microbiologist Dr Sofie De Meyer has searched the world for better sheep feed and set her sights on a South African plant called Lebeckia ambigua.

The deep-rooted perennial is a legume that makes its own fertiliser from nitrogen in the air, using bacteria residing in nodules or "little potatoes" on the roots.

Field trials on marginal farmland in Western Australia have been successful and the Lebeckia seed could be commercially available by the end of the year.

Ongoing research is investigating the symbiotic relationship between the plant and the bacteria to make sure the seed comes ready to start fixing nitrogen as it grows on farm.

It's a fascinating project that keeps De Meyer interested and entertained because she has always enjoyed "solving puzzles or problems", even before she knew what it was to be a scientist. She believes "agriculture definitely has amazing opportunities for the future".

"The population is only going to grow, more people will need to be fed and it's going to be harsher, because of climate change," she says. "So there are lots of challenges around growing food in a sustainable way that need bright minds to solve."

De Meyer makes an effort to share her research at farmer workshops, field days and festivals, such as the Nannup South West FoodBowl Festival. She has been recognised as a rising star of research with a WA Tall Poppy Award in 2017 and previously in the Fresh Science and FameLab.

DID YOU KNOW?

Australia is the world leader in lamb-meat production.

Sheep typically fatten up on winter pastures of legumes like clover and alfalfa, but these dry off in summer, leaving farmers to rely on wheat or barley stubble. It's a costly, time-consuming practice, and limits the number of sheep on a farm.

The new perennial feed Lebeckia has the potential to open new areas to sheep farming, improve sheep health and productivity and, over time, fertilise the soil for other crops.

Dr James Waldie. Picture: BAE Systems Australia

RUST NEVER

SLEEPS

Dr James Waldie is living proof the study of aerospace engineering can lead to any number of careers

WALDIE IN HIS 41 YEARS on Earth has improved the aerodynamics of Formula 1 cars, designed his own space suit, helped unmanned aerial vehicles (UAVs) fly better and mastered the prevention of corrosion in the global fleet of F-35 Joint Strike Fighter aircraft. "Space was something that really attracted me (as a young person) – exploring space is being able to answer the big science questions with advanced technology and pioneering spirit," he says.

He was accepted into Aerospace Engineering at RMIT in Melbourne, managing to fit in a double degree with business administration.

Waldie first set his sights of Formula 1, landing two months of work experience with the Arrows F1 racing team.

"The aeronautical industry essentially encompasses F1 because it's all about aerodynamics and advanced materials and composite structures and advanced propulsion," he says. "It was a fascinating time and I was fabricating parts and involved in testing at Silverstone (race track in England) and pit stop practice. There are a lot of Australians in F1 – Daniel Ricciardo just won the Monaco GP, so there's a driver – but there's a heap of Australian engineers involved, too."

The aeronautical industry essentially encompasses F1 because it's all about aerodynamics and advanced materials

The work experience paid off because it showed Waldie he actually wanted to pursue his first passion: for space.

By 2002, Waldie was back to Australia and working with BAE Systems. "I wanted to work in industry (rather than pure research) and to work for a pre-eminent aerospace engineering organisation" he says. "While there were no spacesuit jobs at BAE, some other jobs were attractive. I worked on UAVs. We've done some amazing things ..." The group designed and tested the UAVs, flying them all over Australia, including around Royal Flying Doctor Service planes and other manned aircraft around West Sale (Victoria) in a test of shared airspace.

"There's a lot of talk today about how to do that but we were doing it 10 years ago," Waldie says. "We were, and still are, at the forefront of UAV technology, particularly avionics. It's another example of how Australians are at the leading edge of technology."

After a stint at MIT in Boston he returned to BAE Australia to join the corrosion group in Melbourne. "BAE has been selected to supply corrosion monitoring and prognostic technologies into the largest defence program on the planet: the F-35 Joint Strike Fighter," he says. "We provide that expertise to the global fleet in the US, the UK – all the aircraft operators in the world."

The group has supplied sensors to be installed on the aircraft to monitor corrosion, as well as predictive software that lets maintenance crews know when corrosion is likely to appear in the aircraft in the future and how to deal with it.

Aircraft are particularly susceptible to corrosion because they are largely made of aluminium alloys that can corrode readily when exposed to moisture and salt. Australia alone spends about $240 million a year just keeping on top of corrosion in its own defence aircraft, says Waldie.

"A lot of students think you have to leave Australia to work on the world's largest programs, engineering pursuits or make the biggest discoveries. There are many examples where you don't and this is a good one, where the world is looking to us for this expertise."

MAKING IT GO FASTER

The most important consideration in Formula 1 car design is aerodynamics. The two prime concerns are:

THE CREATION OF DOWNFORCE to help push the car's tyres on to the track and improve cornering forces.

THE MINIMISATION OF DRAG, which acts to slow the car down.

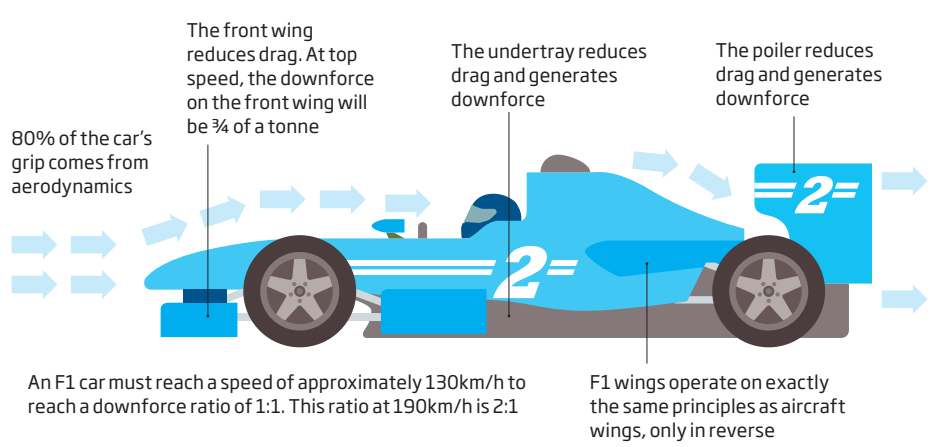
Aerodynamics became a strong feature of F1 in the late 1960s when several teams began experimenting with race wings or aerofoils, which operate on exactly the same principle as aircraft wings, only in reverse.

Air flows at different speeds over the two sides of the wing and this creates a difference in pressure – known as Bernoulli's principle. Plane wings create lift, while race car wings create negative lift or downforce.

By the mid-1970s "ground effect" downforce had been discovered. Lotus engineers designed the underside of their car to make the entire chassis act like one giant wing which sucked the car to the road.

The sport's regulators have tweaked and tightened the regulations on car design, making design advances more incremental. However, every additional kilogram of downforce equates to several milliseconds of lap time saved, driving teams to continue to invest in wind-tunnel programs and computational fluid dynamics, the two main forms of aerodynamic research.
Source: formula1.com

DEALING WITH AERODYNAMICS



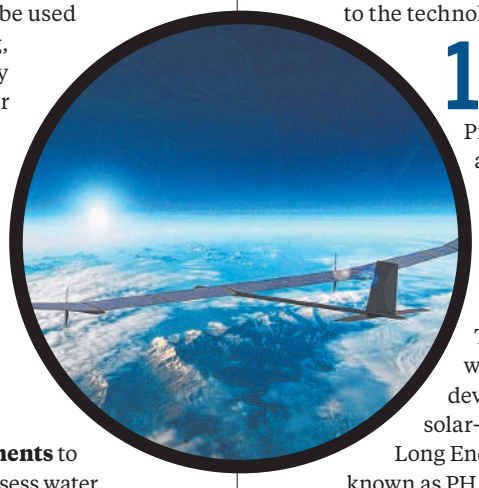
DID YOU KNOW?

Corrosion is defined as the destructive and unintentional degradation of a material caused by its environment. Almost all environments can cause corrosion to some degree, since the corroded state is the more stable. A common type of corrosion is rust, which is found on iron and steel structures. In this type of corrosion, iron is reacting with oxygen to form iron oxide compounds. Oxygen can come from air or water. Iron oxide is more stable than pure iron or steel, so rusting is very common. Rust prevention is actually a means of retaining a less stable, or higher energy, state. It is estimated 5 per cent of an industrialised nation's income is spent on the direct costs of preventing corrosion.

Source: University of NSW

UNMANNED AERIAL VEHICLES EVERYWHERE

THE LIST OF uses for unmanned aerial vehicles (UAVs), or drones, just keeps getting longer as humans continue to find innovative uses and designing and upgrading capabilities for the craft. UAVs are used in remote sensing. Decked out with the latest sensors, they can be used for geological surveying, agriculture, archaeology and any number of other fields.



Different kinds of sensors can use:

Lasers to measure distance.

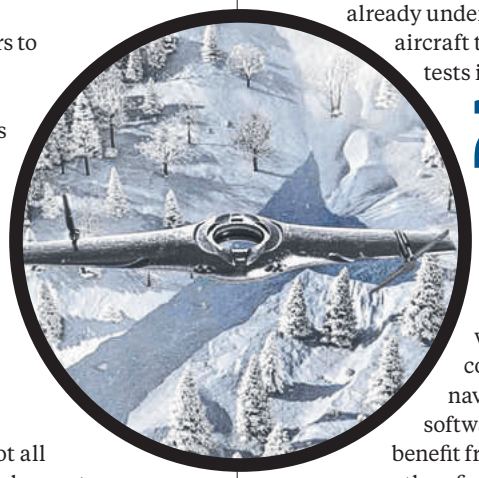
Heat detectors to detect the temperature of livestock, the presence of water and for surveillance and emergency response.

Multi-spectral instruments to count plants and even assess water quality.

Visual spectrum sensors to survey and map land.

Biological sensors to take air quality readings and check for specific micro-organisms or organic compounds.

Electromagnetic sensors to gather geological information to help locate minerals, oil and natural gas.



The surveillance capabilities of UAVs are apparent but they are not all covert. Farmers can use drones to monitor livestock on vast spreads of land; scientists can watch large numbers of wild animals without interfering with their habitats or habits; and fire departments can track and map bushfires.

UAVs are used in video and movie production and have come into their own in live entertainment. Intel has begun creating light shows using the technology and used more than 1200 Shooting Star drones to fly above PyeongChang for the Opening Ceremony of the 2018 Olympic Games, breaking a Guinness World Records title. The same tech has been used above the Sydney Harbour Bridge for Vivid Sydney and at the 2017 Coachella Music Festival in the US.

Elsewhere, hi-tech UAV advances keep pushing the limitations of drones. BAE Systems is working on three new approaches to the technology:

1 In May, working with UAV specialists Prismatic, BAE announced plans to develop a new solar electric UAV with the potential to fly for up to a year before needing maintenance. The two companies will collaborate on the development of the new solar-powered High Altitude, Long Endurance (HALE) UAV known as PHASA-35, with work already under way to prepare the first aircraft to be ready for flight tests in 2019.

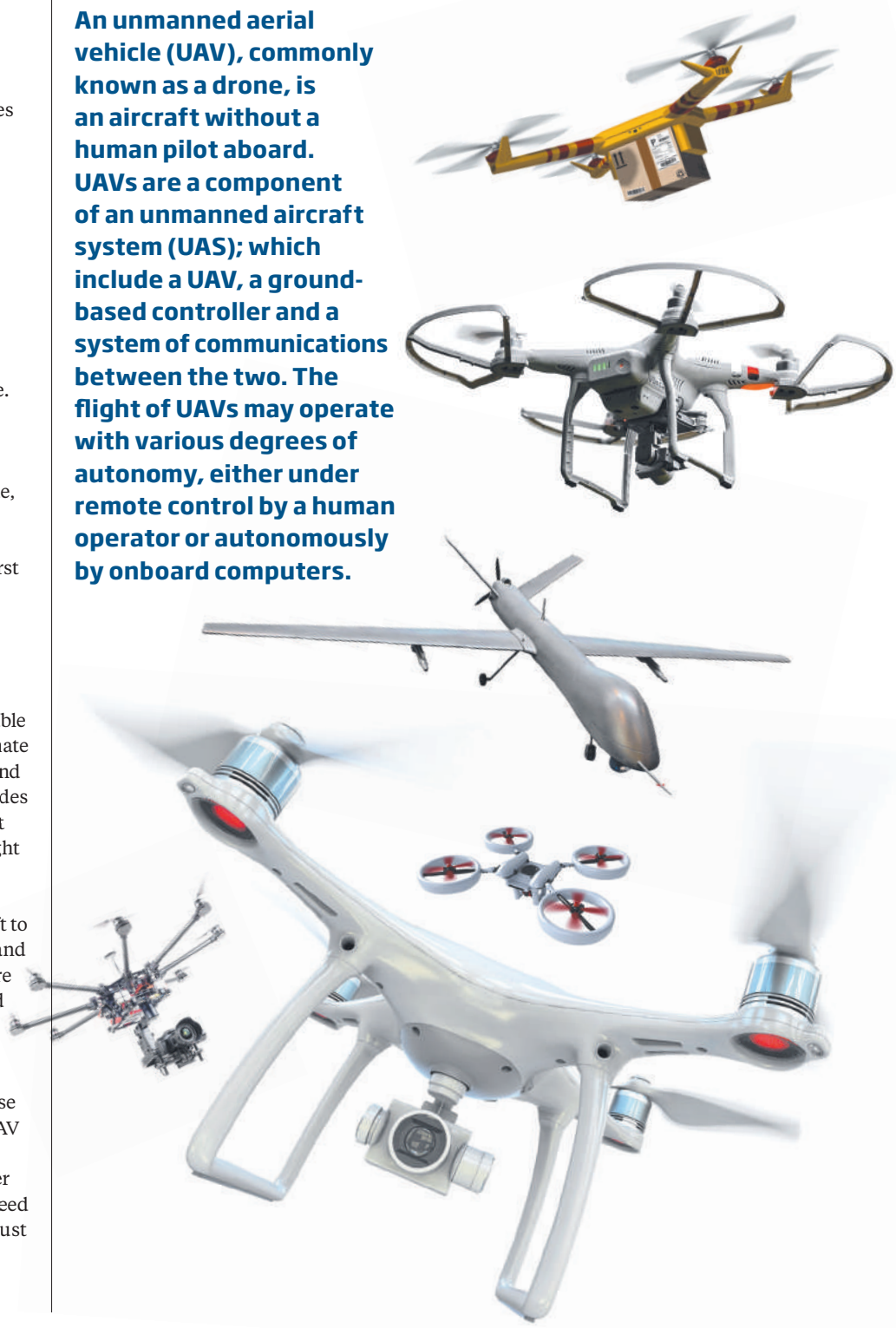
2 With Cranfield University, BAE is working on an Adaptable UAV, which can alternate between fixed-wing and rotary-wing flight modes in the same mission. It would use adaptive flight control and advanced navigation and guidance software to allow the aircraft to benefit from the greater speed and range than fixed-wing aircraft, before alternating to rotary-wing mode to hover and achieve vertical takeoff and landing.

3 With the University of Manchester, BAE has successfully completed the first phase of flight trials for MAGMA – a small-scale UAV using a blown-air system to manoeuvre the aircraft – paving the way for future stealthier aircraft designs. The concept removes the need for complex mechanical moving parts to adjust flaps to control the aircraft during flight.

unmannedsystemstechnology.com/tag/bae-systems/

DEFINITION

An unmanned aerial vehicle (UAV), commonly known as a drone, is an aircraft without a human pilot aboard. UAVs are a component of an unmanned aircraft system (UAS); which include a UAV, a ground-based controller and a system of communications between the two. The flight of UAVs may operate with various degrees of autonomy, either under remote control by a human operator or autonomously by onboard computers.



ENGINEERING STUDENTS SPREAD THEIR WINGS

RMIT Professor Cees Bil does not shy away from the hard truth: if you want to become an aerospace engineer, get used to the idea that your years at university will be hard work. The payoff, says the professor in aerospace systems design, is: "If you can pass the finish line, there's a great profession open to you.

"I didn't pass all of my subjects the first time, but don't give up. What drove me was an inquisitive mind and a passion for understanding how things fly and work, and you need that get through university because it's going to be hard work and you need persistence."

Prof Bil was educated in The Netherlands at Delft University of Technology in the late 1970s, finishing with a Masters of Science (aerospace) in 1981. "The university where I studied was quite brutal – their curriculum is very tough and you have to work very hard. I remember I went to all the lectures ... but I knew that if I didn't I wouldn't pass," he says.

Things have changed a bit since then, and students are less likely to show up for every class, he says, but the hard work still features. Prof Bil says it's a necessary feature of the profession because future aerospace engineers will work in "safety-critical environments".

He says he never left university, choosing to become a lecturer on the subject after finishing his PhD. "I liked to teach young people what I know and hopefully some of the fire that burns inside me about aerospace engineering I can pass on to others, passing on the torch so to speak," he says.

However, being academic does not isolate him from the "real world", with the opportunity to work with students and on industry research and projects. Some of that work has included unmanned aerial vehicles or UAVs, with one research project attracting interest from the defence sector.

"UAVs are a growing area of research all around the world," he says. "My involvement has mainly been in the design of them. One of them is a UAV that can fly in the air as well as underwater. I'm not aware of anyone else successfully getting that going."

Prof Bil believes the rocket-like UAV will be useful for submarines: "It's a rocket with highly compressed air that pushes the vehicle out of the water. The wings are folded in the water and then unfold to allow it to fly away. When it comes back ... it folds the wings again and dives back into the water. That's the concept. (It could return) to the sub and those on board can see what has been recorded, without the sub ever surfacing, so it's safe."