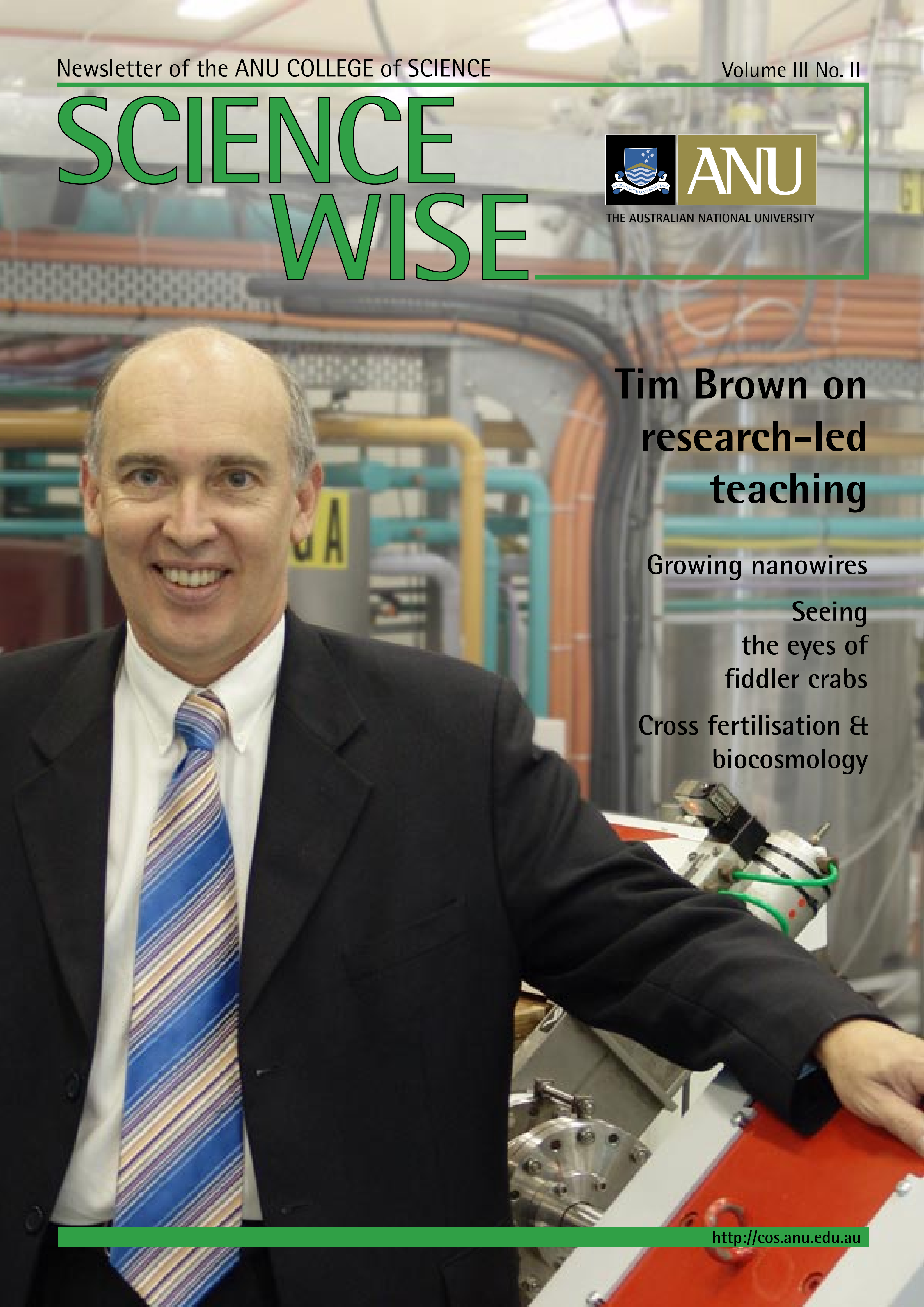
Newsletter of the ANU COLLEGE of SCIENCE

Volume III No. II

SCIENCE WISE

THE AUSTRALIAN NATIONAL UNIVERSITY



Tim Brown on research-led teaching

Growing nanowires

Seeing the eyes of fiddler crabs

Cross fertilisation & biocosmology

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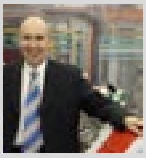
Cover image:

Professor Tim Brown is the Dean of the new ANU College of Science (see story on page 3). Image by Tim Wetherell.

ANU THE AUSTRALIAN NATIONAL UNIVERSITY

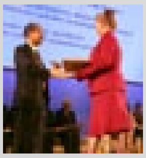
ScienceWise News 1

Deep abyss unveiled, ANU to be part of the world's most powerful telescope and a new Director for RSES.



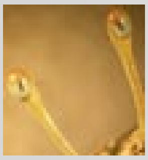
From words into actions 3

Tim Brown explains what 'research led teaching' actually means when put into practice.



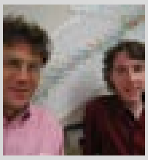
Award to RSBS geneticist 5

Professor Jenny Graves has been awarded one of five international awards for world-leading women in science.



The eyes have it 6

Have you ever looked into the eyes of a fiddler crab? You might be amazed at what you see.



Cross fertilisation, life & the Universe 7

Dr Charles Lineweaver explains biocosmology and the joys of cross disciplinary studies.

Growing nanowires 9

Researchers at Electronics Materials Engineering are growing nanoscale wires under drops of gold.

An inner landscape 10

Is it modern art or 3D cartography?
Find out what hung under the stairs at RSBS 25 years ago.

SCIENCE WISE NEWS

DEEP UNDERWATER ABYSS

Researchers from ANU, CSIRO and Geoscience Australia have scanned the canyons offshore of Kangaroo Island in South Australia to gather data about the deep-sea features and the biodiversity they support. They found that some of the depressions go much deeper than the Grand Canyon.

The AUSCAN (AUStralian CANyons) II voyage took place earlier this year. It followed on from an ANU-led mission in 2003 that uncovered the ancestral courses of the River Murray.

"What we have unveiled is a set of underwater channels like streams found today in the Blue Mountains, in New South Wales, adjacent to the large incised plateaus, but the dimensions are more than four times higher" said project leader Professor Patrick De Deckker, from the ANU Department of Earth and Marine Sciences.

"The image we have created clearly shows well-defined channels that must be transporting water and sediments from the upper parts of the shelf down to the deep-sea, a descent of more than 5000 metres.

"These canyons are rapid conduits of nutrients and food down to the deep ocean where diverse, but sparse life must exist. We know, for instance, that the area is visited by whales and other vertebrates."

Dr Stephen Eggins from the ANU Research School of Earth Sciences took water samples from depths well below 5,000 metres during the mission to determine the nature of nutrients on the deep-sea floor. Analysis was provided by colleagues from the CSIRO.

The ANU team, which included a number of postgraduate students, also obtained sediment cores from platforms on the canyons to retrace the history of these underwater abysses.

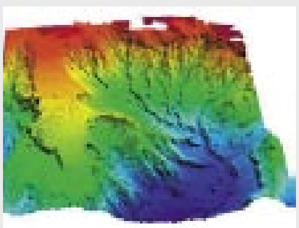


Image Geoscience Australia

MOST POWERFUL TELESCOPE

ANU will help build the world's most powerful telescope after signing a Memorandum of Understanding to construct the giant telescope with an international consortium of research organisations.

Artist's impression of the Magellan Telescope. (courtesy of Carnegie Observatories).

The Giant Magellan Telescope, or GMT, is in the preliminary planning stage and is likely to be one of the first of a small number of next generation Extremely Large Telescopes (ELTs) due to come on-line in the next two decades.

The GMT will detect and study planets around other suns, probe the dark matter and dark energy that controls the expansion and development of the cosmos, and unlock the secrets of star and planet formation.

As part of the GMT consortium, ANU joins an elite group of research and teaching institutions in the US to plan the detailed design of the telescope, including the Carnegie Institution of Washington, Harvard University, Massachusetts Institute of Technology, the University of Arizona, the University of Michigan, the Smithsonian Institution, the University of Texas at Austin and the Texas A&M University.

Director of the Research School of Astronomy and Astrophysics, which is based on Mt Stromlo in Canberra, Professor Penny Sackett, signed the Memorandum of Understanding in Texas in April.

"Stromlo has always been at the forefront of astronomy and its instrumentation. This partnership is a giant step toward the astronomy of the next decade, and will ensure that The Australian National University – and Australia – remains at the cutting edge of scientific research into our universe," Professor Sackett said.

Based on a superb observing site in northern Chile, the telescope is expected to "see first light" in 2015.

More info: director@rsaa.anu.edu.au

NEW DIRECTOR OF RSES

Professor Brian Kennett has been appointed as the new Director of the Research School of Earth Sciences (RSES). He takes up the position in September.

Professor Kennett is currently Professor of Seismology at RSES. He joined ANU in 1984 as Professorial Fellow at RSES. In his time at ANU he has been Interim Director of RSES in 1993, Chair of the Board of Advanced Studies and Pro-Vice-Chancellor from 1994-1997. From 1999-2003 he was President of the International Association of Physics of the Earth and Planetary Interiors.

Professor Kennett's leadership in his field has won him numerous awards, including the Adams Prize of the University of Cambridge (1983), the Jaeger Medal of the Australian Academy of Sciences (2005) and the Murchison Medal of the Geological Society of London (2006). He was made a Fellow of the American Geophysical Union in 1987, a Fellow of the Australian Academy of Sciences in 1994 and a Fellow of the Royal Society, London in 2005.

"Professor Kennett is one of Australia's most eminent earth scientists. He has long made an outstanding contribution to RSES and the ANU," Professor Chubb said.

Professor Kennett responded: "The Research School of Earth Sciences is a great Australia asset, with strength in many areas of the earth sciences. My aim will be to enhance interactions between disciplines to provide a multi-faceted view of the Earth and its interior."

From words into action

by David Salt

'Research led teaching', that's the mantra in the ANU College of Science.

"If it's good enough to research, it's important that it drive what and how we teach," says Professor Tim Brown, Dean of the ANU College of Science and the Faculty of Science. "Even more importantly, all our students need the opportunity to see research taking place and participate in it."

But what does that mean in reality?

"It means we're building strong connections between our research strengths and our teachers," says Professor Brown. "It means the people doing the research, some of the finest researchers in the world, are having a real input into our degree programs, how they're structured and what they contain.

"It means our students have the opportunity to be mentored by these researchers, and will have access to cutting edge technology. For the best and brightest, this happens from day one, but all get options for research at some stage."

"And it means that teachers across Australia will also have increasingly better access to learning about the research that is driving today's science.

"And all of this will increasingly rely on the new college structure. Indeed, I think that the formation of the ANU College of Science is an important step in formalising what I have seen as my chief mission as the Dean of the Faculty of Science – that is to lead Australia in research-led teaching in science.

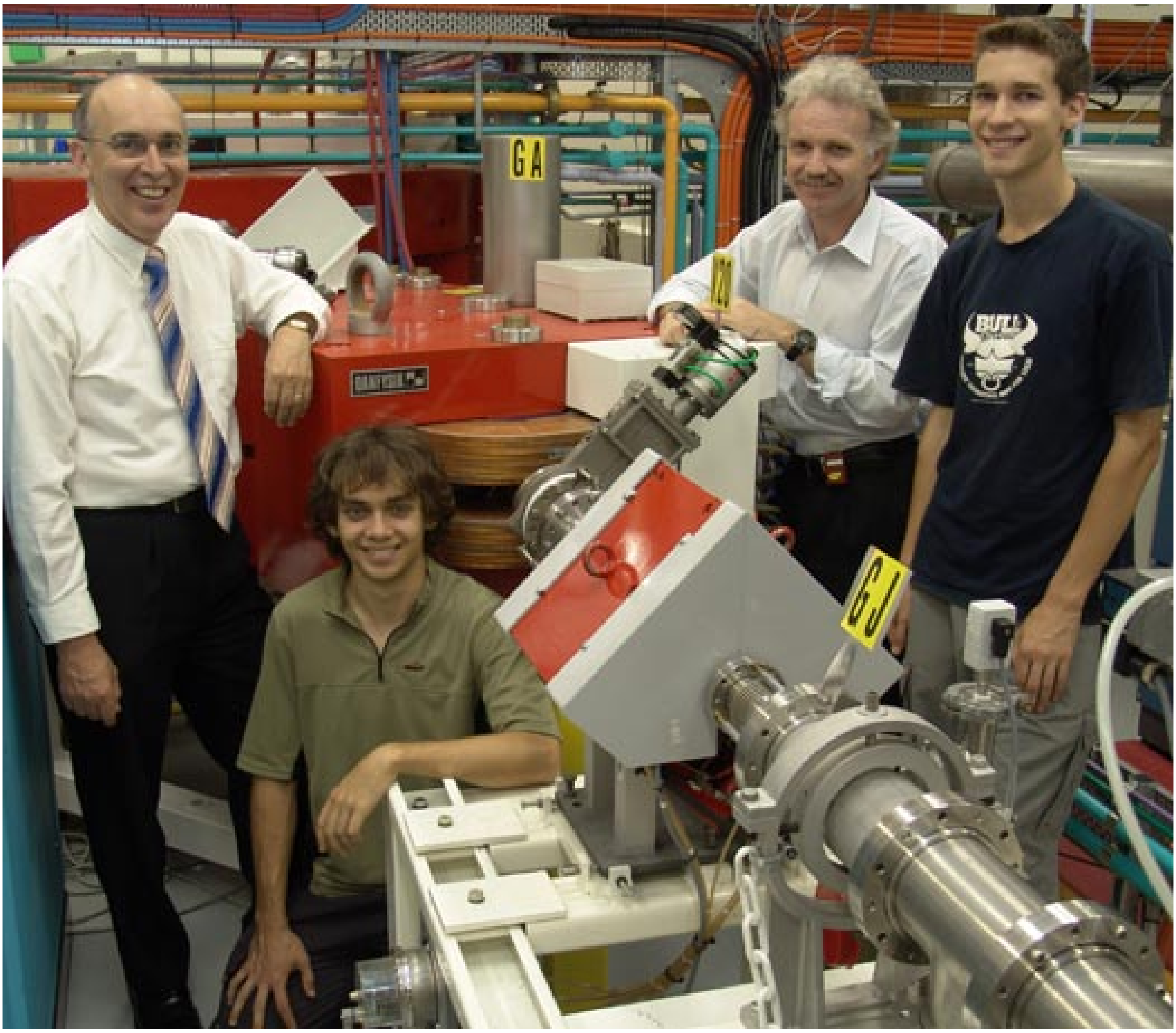
"The Faculty of Science has always been strong in mixing research and teaching," Professor Brown is quick to point out. "However, in recent years, we've been designing and delivering a range of innovative degrees. In 2003 we began our Bachelor of Philosophy degree (PhB) in an effort to offer an exciting and challenging degree to the nation's finest young science students. We only accept the highest achieving students into the degree and then they need to maintain a a high average mark (80) to stay in it. To help them meet this high standard PhB students receive personal mentoring from top researchers and the ability to engage in real research throughout their degree. This is a challenging degree aimed at producing tomorrow's top researchers.

"About the same time as we introduced the PhB we also started up a Masters in Contemporary Science (MCS). This is aimed at professional science teachers who want to re-engage with what's happening at the cutting edge of research. Of course, it's always a big ask for a full time professional to take time out to engage in full time study, but the MCS has proved enormously successful.

"So the Faculty of Science takes research very seriously in its teaching. However, now the ANU College of Science promises to take this process a whole lot further, and the impacts will be felt by everyone associated with the College – and that means our students, our teachers and our researchers.

> *"the formation of the ANU College of Science is an important step in formalising what I have seen as my chief mission as the Dean of the Faculty of Science – that is to lead Australia in research-led teaching in science"*

"Probably the most obvious upfront changes will revolve around a greater engagement between the research schools and the structure of science degree courses. While there are already many informal and formal links (such as joint appointments), the college structure serves to formalise the interaction. For example, there are ten discipline subcommittees within the College that regularly meet to review structure and content of the many courses we offer through the Faculty of Science. Six of the ten chairs of these subcommittees have a strong connection outside of the Faculty of Science, usually the research schools. This makes plain that it will increasingly



(From left to right) Professor Tim Brown, Robin Stevenson (a PhB student), Professor Aidan Byrne (Department of Physics) and Sean Hodgman (another PhB student) in the LINAC booster hall of the Department of Nuclear Physics (Research School of Physical Sciences and Engineering).
"PhB students receive personal mentoring from top researchers and the ability to engage in real research throughout their degree," says Professor Brown. (Photos by Tim Wetherell)

be the research strengths at ANU that are informing our teaching direction.

"In some cases this may even lead to the formation of whole new degrees. This year we've offered for the first time an Honours Bachelor degree in Global and Ocean Sciences (BGOS Hons). This was directly connected to a proposition put to the Vice Chancellor by a couple of our esteemed earth science researchers, one from the Research School and the other from the Faculty. It was identified there was a need for this type of degree and that ANU had unique research strengths in this area.

"The response to the proposition was the establishment of several joint research/ teaching positions across the campus in ocean and earth sciences, and the creation of the BGOS (Honours) degree. This is notable for a couple of reasons. First, we're now offering Honours entry science degrees where students can enrol directly into an Honours degree providing they can meet the high entry requirement and sustain high grades through the degree. In so doing they sign up for a degree rich in research. This also applies for our straight BSc.

"Second, an approach focussed on research-led teaching is seeing more joint staff appointments being made in which teaching staff also have a part appointment in an affiliated research school. This can only enhance the connection between research and teaching.

"And affiliation should also lead to more teaching-and-research staff having greater opportunities to undertake some of their research in research schools. The College structure must build bridges that make it easier to move from research school to faculty department and vice a versa.

"So the phrase 'research led teaching' has meaning at many levels. Courses will reflect research priorities and approaches, students will have more opportunities to carry out research and interact with researchers, and researchers will be more engaged with teaching and students.

"The Faculty of Science has been moving in this direction for some time but the structure of the new ANU College of Science will greatly assist us in converting the mantra of 'research led teaching' into significant outcomes for students and the university."

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International award to RSBS geneticist

Professor Jenny Graves, an evolutionary geneticist in the Research School of Biological Sciences (RSBS), has recently received one of five international awards given to women scientists for her studies on the evolution of mammalian genomes.

In distinguished company: L'ORÉAL-UNESCO Awards For Women in Science were presented to (from the left) Professor Pamela Bjorkman (USA) for her discovery of how the immune system recognizes targets; Professor Jenny Graves (Australia) for her study on the evolution of mammalian genomes; Professor Esther Orozco (Mexico) for her discovery of the mechanism and control of infections by amoebae in the tropics; Professor Habiba Bouhamed Chaabouni (Tunisia) for her contribution to the analysis and prevention of hereditary disorders; and Professor Christine van Broeckhoven (Belgium) for her genetic investigations of Alzheimer's and other neurodegenerative disorders. Each Laureate received $US 100,000.

Professor Graves was selected as the Asia-Pacific laureate of the L'oréal-UNESCO for Women in Science 2006 awards by a panel of high-profile life scientists led by Gunter Blobel, who received the Nobel Prize for Medicine in 1999. As part of the award, which was presented during week-long ceremonies in Paris in March, Professor Graves received US$100,000 and has been further elevated as an international role model for women in science.

Professor Graves is the Head of the Comparative Genomics Research Group at RSBS and is Director of the ARC Centre for Kangaroo Genomics. She was elected a Fellow of the Australian Academy of Science in 1999, was awarded a Centenary Medal for services to Australian genetics and genomics in 2002 and is the recipient of the AAS Macfarlane Burnet Medal for Biology in 2006.

Her research focuses on the evolutionary history of the human sex chromosomes, X and Y. Her team discovered that the gene on the Y chromosome thought to be responsible for testis development was not located on the Y chromosome in marsupials, which led to two of her former students identifying the correct sex-determining gene present on the Y chromosome both in placental mammals (such as humans and mice) and marsupials which branched off the evolutionary tree some 180 million years ago.

In a research paper published in the prestigious journal Cell, Professor Graves elaborates on this sex-chromosome research, and the implications of her predicted extinction of the Y-chromosome in humans.

Professor Graves receives her award.

Professor Graves said it was a great honour to receive an award that aimed to celebrate the contributions of women in science.

"This initiative also recognises talented early-career women researchers with a fellowship to pursue their research. These wonderful young women are the scientists who will be inspiring the next generation of young women to study science and pursue a career in the field.

"The message we all want to get through to young women – and young men – is that science is a wonderfully exciting and fulfilling career. I feel very lucky that I'm paid for doing what I've always wanted to do – detective work on the order and organisation of living things through genetics – and that this has allowed me to work with some terrific people and make some exciting discoveries," Professor Graves said.

The eyes have it

by Ali Alkaladi

Fiddler crabs (*Uca vomeris*) live in the flat world of tropical mud or sand flats and are active during low tide. They can see 360 degrees at the same time, which means they can spot predators coming from any direction.

The crabs carry their eyes on stalks, and resolution varies across the visual field. The eyes can be used as periscopes. Crab eyes, like those of insects, are compound eyes. They are composed of large numbers of unit eyes called ommatidia.

Fiddler crabs are very visual animals and their behaviour is currently being analysed by research groups in the Research School of Biological Science and the Department of Botany and Zoology (Faculty of Science). The crabs employ a variety of visual signals from claw-waving displays to brilliant body colours.

My project is concerned with the design of the eye in fiddler crabs. Very little is known about the detailed properties of their visual system.

In my group, a number of projects deal with the visual behaviour of these crabs. Tanya Deto studies the meaning of colour in fiddler crabs. Martin How is investigating their claw waving displays. Jochen Smolka is looking at how they respond to predators and Dr Jan Hemmi and Dr Jochen Zeil are involved in research on how they process information to make decisions.

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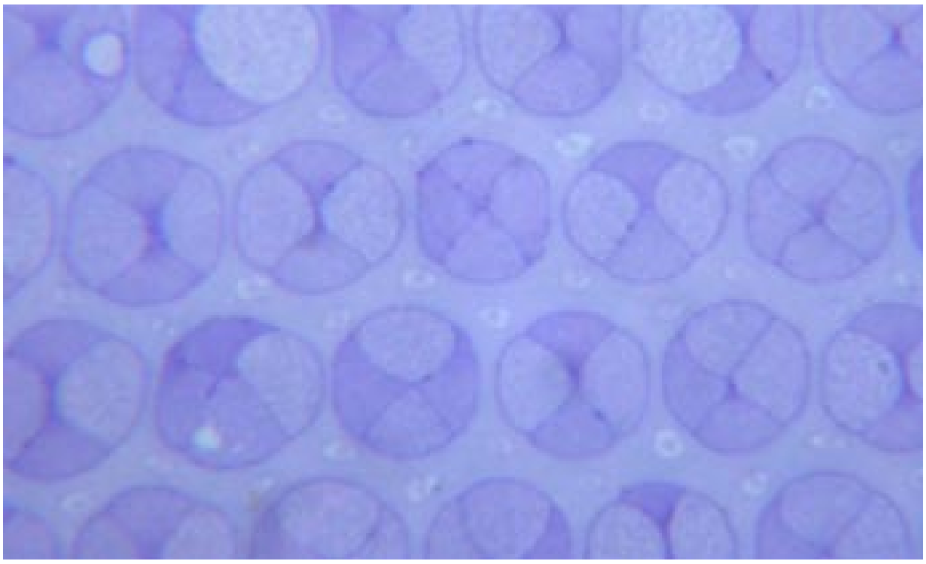
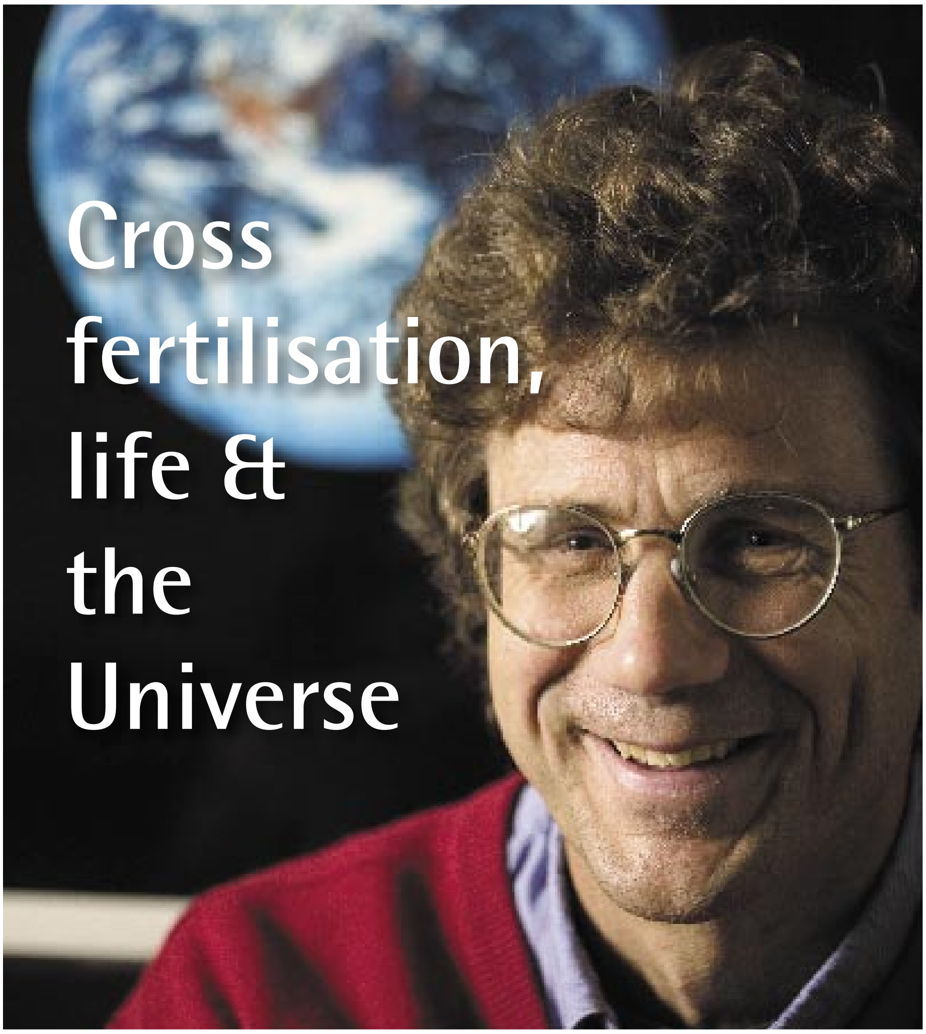
(The research is supported by a PhD Scholarship of the Ministry of Education, Saudi Arabia.)

(Above) The eyes of a fiddler crab as photographed by Ali Alkaladi. This image won the 2005 RSBS Student Photo Competition.



(Right) A cross section of the fiddler crab compound eye shows the regular array of four crystalline cone cells in many ommatidia. Ommatidia are the individual elements which make up a compound eye. Each ommatidium works like a single pixel in a digital camera. It has a lens and a crystalline cone which together focus the light on eight photoreceptors which form a single light sensitive structure, the rhabdom. The photoreceptors in one ommatidium share the same optical axis but probably analyse different aspects of the spectral and polarization properties of light.

Cross fertilisation, life & the Universe



by David Salt

"If we are to understand the origin of life and whether we are alone in the universe, the strong traditional boundaries between the life sciences and physical sciences will have to come down," says Dr Charles Lineweaver.

And Dr Lineweaver practices what he preaches. In an effort to gain greater insights on the place of life in the Universe he's been breaking down these barriers for many years applying astronomy to biology, biology to earth science, chemistry to biology and physics to chemistry. Dr Lineweaver is a cosmological polymath, a wandering mind happily cherry-picking information from across the broad frontier of science to test the details of various models on how the Universe evolved. So far he's made important contributions to such questions as: How old is the Universe? What fraction of stars have planets? Where in the galaxy could life sprout? How does our Earth compare to other earths? And: have other forms of life ever emerged on Earth?

Dr Lineweaver is no stranger to the big topics of the Universe. He was part of the Cosmic Background Explorer team at the University of California which discovered fluctuations in the cosmic microwave background radiation in the early 1990's, one of the biggest breakthroughs in cosmology in the 20th Century.

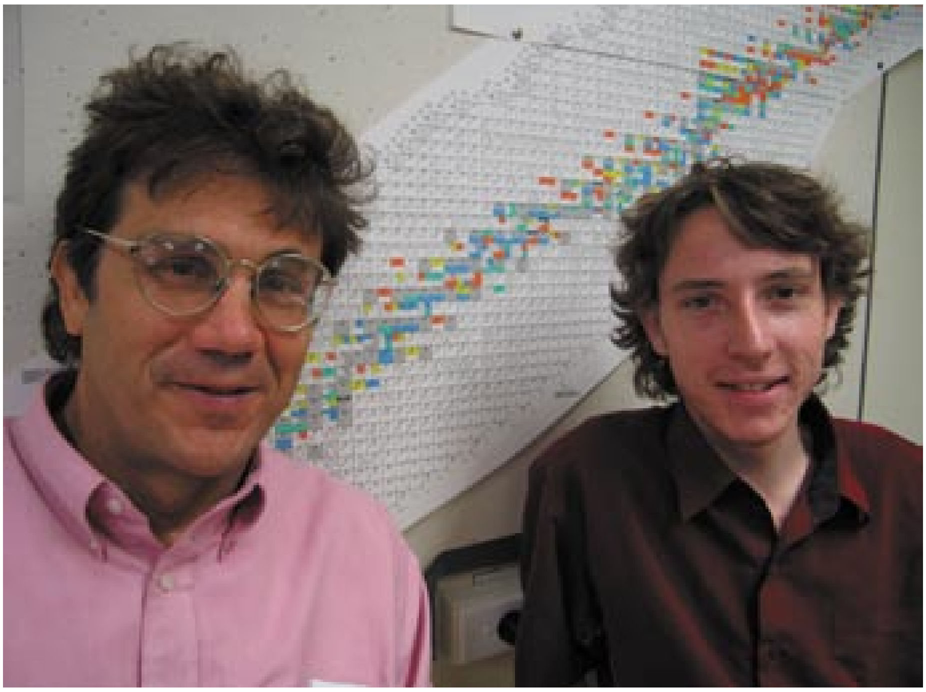
"I grew up in astronomy and cosmology, but I became engaged in the topic of life and the Universe while teaching a course titled 'Are we alone?' at the University of New South Wales," explains Dr Lineweaver. "There's also the fact that my father was a biologist so I've always had the life sciences in the background."

Now Dr Lineweaver is based at ANU where he is the coordinator of the recently formed Planetary Science Institute (PSI), a joint venture of the Research School of Astronomy and Astrophysics and the Research School of Earth Sciences.

"It's a great place to synthesize what we know about the Earth with what we know about other earths ," he says. "Our aim is to increase our cross-disciplinary understanding of the diversity of planets in the Universe, and what part of that diversity is required for life. In part this is done through discovery and the critical study of the formation, evolution, and fate of planetary systems throughout our galaxy, including our own Solar System.

"It's an exercise in cross fertilisation where the insights from astronomy and astrophysics are brought to bare on our understanding of earth science and vice a versa.

"Of course, while crossing disciplines can be tremendously exciting it is also likely to raise tensions as different cultures clash. Take for example the origin of our Moon. For astronomers it's a problem in which angular



Dr Lineweaver with James Smith, a third year physics student who is working with the Planetary Sciences Institute to produce a movie showing the evolution of the elements over the life of the Universe.

momentum is the key. Most astronomers are satisfied with the idea that a planet the size of Mars collided with the Earth about 4.5 billion years ago and this impact formed the Moon. Earth scientists are more skeptical since the geological evidence for such a giant impact is more ambiguous.

Two approaches yield two versions of what is and is not acceptable.

"When you apply different approaches to different fields you frequently generate important insights on what's happening. For example, here at the PSI we're applying our understanding of cosmic processes to draw up a chart of how the elements have evolved over the lifespan of the Universe. We're also attempting to understand the consequences for life when planets originate with a different elemental mix than our own."

So, what are the chances of life being out there?

"There are many reasons to believe that terrestrial planets in habitable zones are present throughout the Universe," says Dr Lineweaver. "Rocky planets are formed in accretion disks and accretion disks are necessary ingredients in our best models of star formation. The latest observations and simulations are consistent with the possibility that rocky planets orbit the majority of stars.

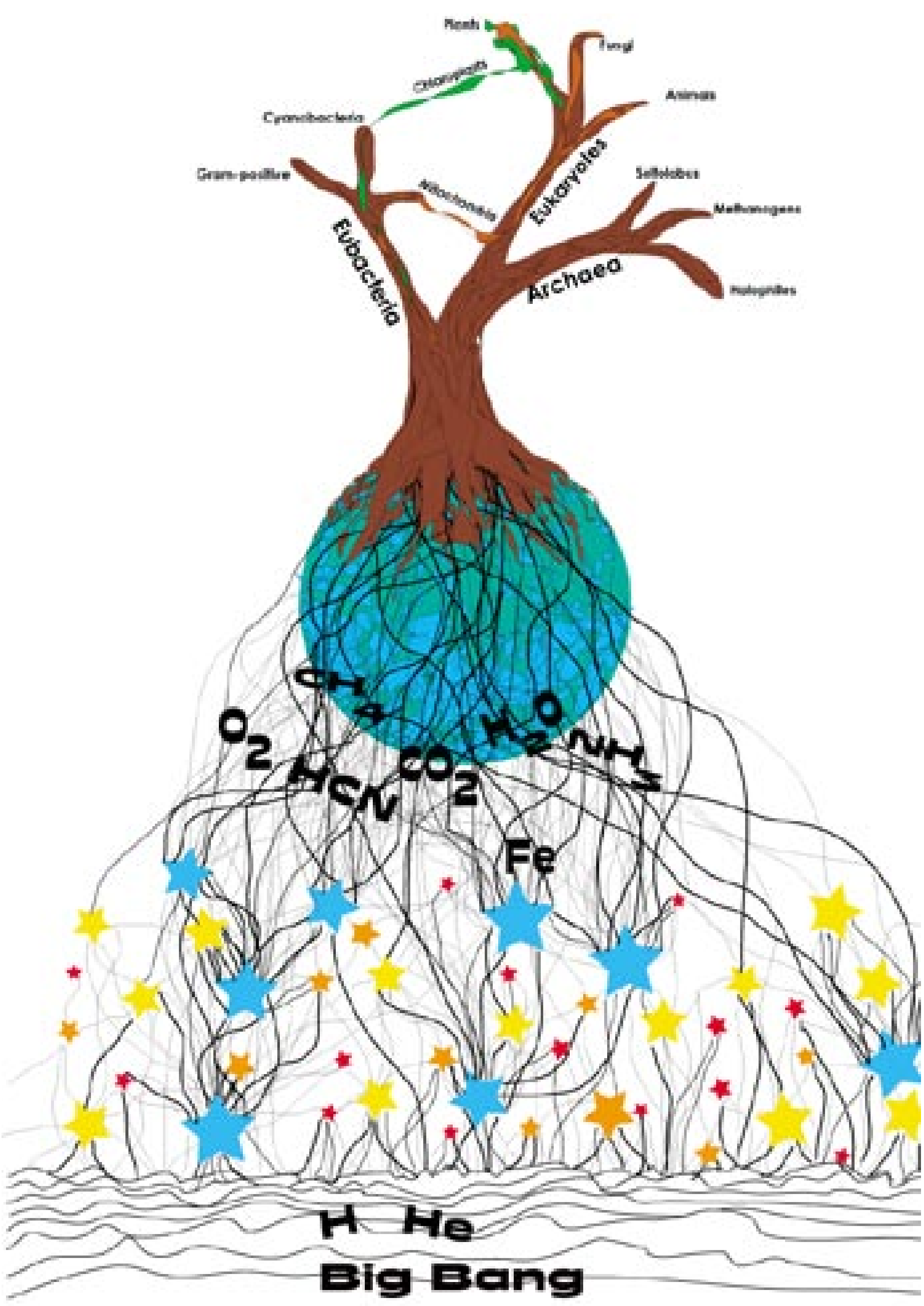
"Now, add to this that life formed on Earth soon after the planet formed, and that life is made of the most common elements available in the Universe. These facts suggest that life may be common on terrestrial planets throughout the Universe."

And what's it like for cosmologist based half time in an institution focused on earth sciences?

"Earth sciences is incredibly valuable to my interest in biocosmology," says Dr Lineweaver. "It's also very challenging. There's a very steep learning curve. However, I'm getting there. Indeed, just like all keen earth scientists, I now have some debris from a supernova -a rock - proudly sitting on my desk."

More info: Planetary Science Institute website: http://www.mso.anu.edu.au/PSI

Email: Charley@mso.anu.edu.au



A short history of life and the Universe: To understand the tree of life at the top of the diagram you need to appreciate it's cosmological context says Dr Lineweaver. In this diagram he has illustrated this point by showing that life on Earth is contingent on the available chemistry which is based the history of the solar system and matter itself.

"The hot big bang (bottom) produced hydrogen and helium (labeled 'H' and 'He')," explains Dr Lineweaver. "Clouds of H and He gravitationally collapsed to form stars of various masses. The massive stars exploded after a few million years and spewed into interstellar space the ashes from the nuclei that had fused in their cores. After eight billion years of such reprocessing and accumulation, our Sun formed five billion years ago from a gravitationally collapsing cloud of molecular hydrogen contaminated with oxygen, carbon, nitrogen and other heavy elements. The Earth formed from this contamination in the accretion disk around the young Sun. As the Earth accreted, water was deposited on its surface by a continuing infall of comets and water vapour outgassed from hot rocks, just as volcanoes do today. From this aqueous environment life emerged on Earth about 4 billion years ago and branched into the three domains shown at the top."

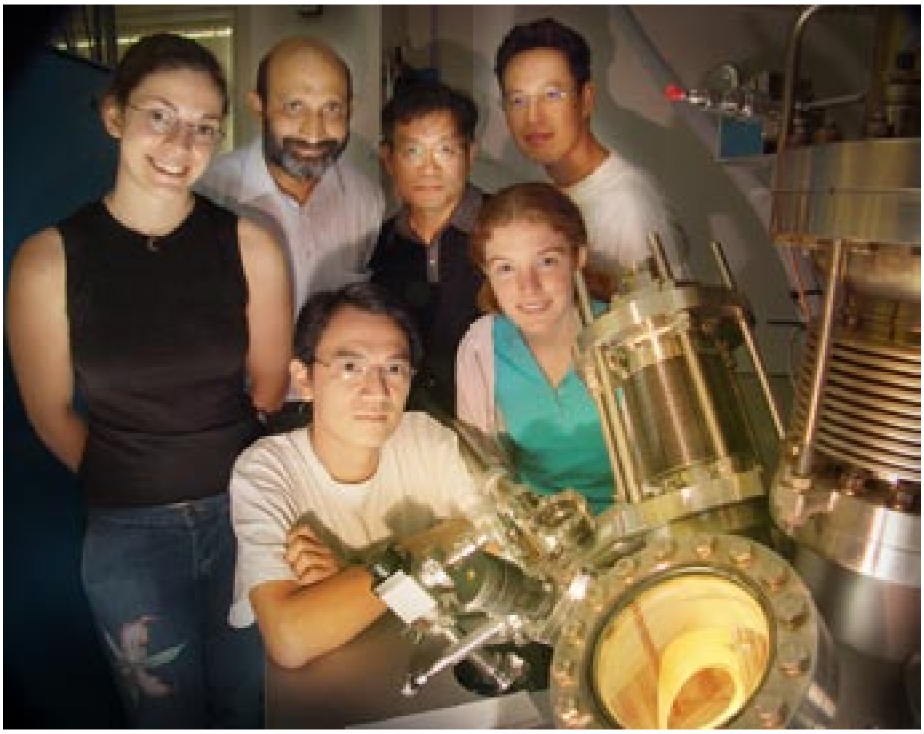
Growing nanowires

by David Salt

The electronics and photonics industries are largely based on a top-down approach to building things. By this we mean you begin with a chunk of material – a wafer of silicon for example – and carve it down to create the circuits you need. These days industry can produce circuits with features only 90 nanometres apart but a top down approach has major problems going smaller than this.

"When you etch out circuits on semiconductors, you create a lot of defects – there are missing atoms which can trap the electrons," explains Professor Chennupati Jagadish. "This isn't a problem when the circuits are big but it becomes a limiting factor when you're working at scale of tens of nanometres. Defects destroy these structures and the notion of carving out intricate three dimensional forms is simply out of the question."

Professor Jagadish is Head of the Semiconductor Optoelectronics and Nanotechnology Group in the Department of Electronic Materials Engineering (Research School of Physical Sciences and Engineering). For more than a decade his group has been building up expertise in working with compound semiconductors using a variety of techniques to create a range of devices including lasers, quantum dots and photodetectors. Now he has turned his attention to growing nanowires.



The nanowire team at EME: (from the left at the back) Ms Victoria Coleman, Professor Jagadish, Dr Yong Kim and Dr Qiang Gao. Up front are Dr Hoe Tan and Ms Hannah Joyce.

"Our success in growing nanowires is testament to the passion shown for this research by everyone in the team," says Professor Jagadish. (Photo by Tim Wetherell)

Nanowires have become the focus of several labs around the world in recent years. These are columns of semiconductor material that are only tens of nanometres in diameter that can be used to make circuits or serve as components in a range of devices.

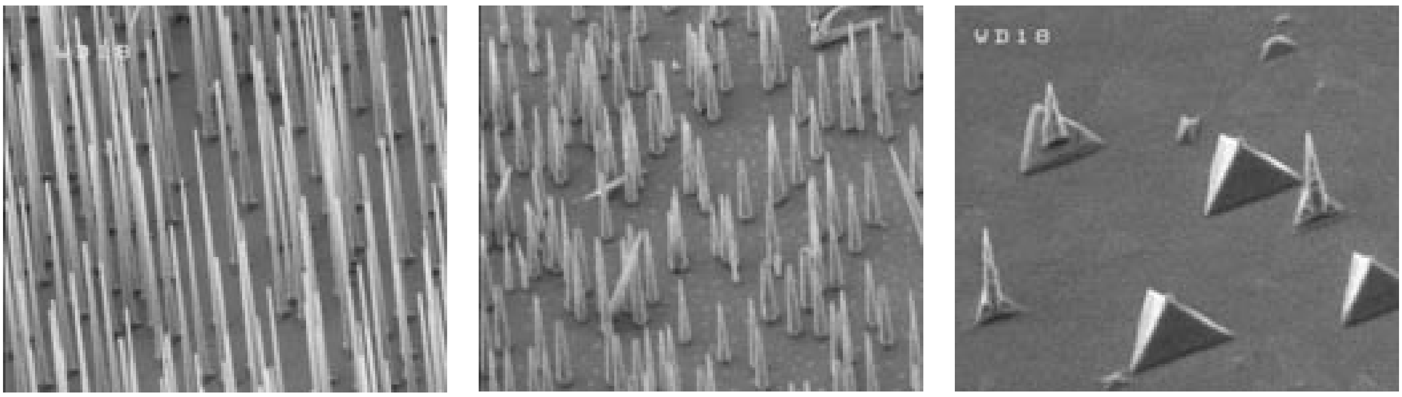
"While you can't carve out working nanoscale structures, it is possible to grow them from the bottom up," says Professor Jagadish. "Our understanding of how to grow nanowires is now proceeding in leaps and bounds and this could prove to be the gateway to a new age in optoelectronics."

So, how do you grow a nanowire?

"To build nanowires we deposit nanoparticles of gold onto a semiconductor wafer of gallium arsenide," explains Professor Jagadish. "We then place the sample into the metal organic chemical vapour deposition chamber and heat the sample to around 600° C. This removes any surface contaminants and melts the gold so it forms an alloy with the gallium from the gallium arsenide wafer. This is a eutectic alloy in which the melting point of the alloy is lower than gold by itself.

"Next we lower the temperature of the chamber to below the melting point of gold but above that of the gallium/gold alloy so it remains molten. At the same time we introduce gases into the chamber containing gallium and arsenic atoms.

"And then the most amazing phenomenon takes place – a tower of pure crystalline gallium arsenide begins to grow under the molten droplet of gold giving you a self-



The critical variables involved in growing nanowires are the size of the gold particles under which they grow, the density and distribution of the particles on the wafer, and the heat at which they are formed. For gallium arsenide the researchers found the optimum temperature was 450°C (image on left). These columns are around 50 nm thick. Thirty degrees warmer and instead of tall thin wires you get shorter, stubbier needles (centre) that are around 200 nm thick at the base. At 510°C you get triangular pyramids (right) which are measured in microns across the base. While they look interesting, have no known useful optoelectronic properties.

assembled nanowire."

The researchers have learnt through trials that the critical variables involved in growing nanowires under gold nanoparticles is the size of the particles, the density and distribution of the particles on the wafer, and the heat at which the nanowires form.

By using different reactive species in the vapour such as indium, gallium and arsenic, it's possible to incorporate different compounds into the nanowire thereby giving it different electro optical properties.

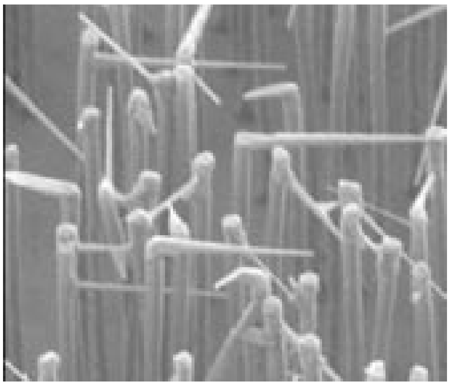
And where will these nanowires be used?

"It's possible that the nanowires we are growing might be used as wires connecting circuits and devices," says Professor Jagadish. "By breaking them from the wafer on which they've grown using ultrasonic treatment they can then be placed into circuits.

"However, we suspect their more significant value will come using them where they grow. They can serve as nanowire lasers, nanowire photo-detectors, photonic crystals and quantum dot lattices. Our next challenge, therefore will be to work out different ways of growing the nanowires in ordered arrays and we're currently experimenting with different ways of achieving this.

"It might take a few years but as our mastery of self-assembled nanostructures begins to match our traditional top-down mass-manufactured capacity it's likely a new world of possibilities will open. It's impossible to say exactly how it will progress. What's important is that Australia build a capacity to engage with these emerging technologies," stresses Professor Jagadish.

More info: Professor Chennupati Jagadish < cxj109@rsphysse.anu.edu.au>



The researchers are devising new ways of growing simple nanowires, compound nanowires and even branched nanowires as shown above. These structures are around 50 nm in width, and they may change the face of optoelectronics.

An inner landscape

Looking like a cross between a cloud and a 3D topological map, the sculpture pictured below was suspended under the stairs at the entrance of the Research School of Biological Sciences (RSBS) back in 1975. However, this was far from abstract art as the multi-tiered model represented the inner form of a plant cell – magnified 140,000 times.

Showing great interest in the model is Professor John Heslop-Harrison (left), Director of the Royal Botanic Gardens in Kew, London. Professor Heslop-Harrison was visiting ANU to give a lecture on the growing threat to plant diversity around the world from human population growth and land clearing.

Explaining the model to him is Professor Brian Gunning from the Department of Developmental Biology.

Photos courtesy of the ANU Archives Program. For more info on the ANU Archives Program: http://www.archives.anu.edu.au/

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