Magazine of the ANU COLLEGE of SCIENCE

Volume IV No. IV

SCIENCE WISE

THE AUSTRALIAN NATIONAL UNIVERSITY

- Reflections of a Summer Scholar
- A Taste for Learning: *Cognitive enhancement in honey bees*
- First Observation of 2D Bloch Oscillations
- Unravelling Ttyh1's Role
- A Tale of Three Timbers

http://cos.anu.edu.au

SCIENCE WISE

Magazine of the ANU COLLEGE OF SCIENCE

Volume IV No. IV (August/September 2007)

ScienceWise is published by the ANU College of Science.

We welcome your feedback. For further information contact the Editor:

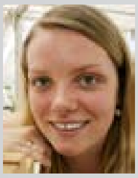
Dr Tim Wetherell

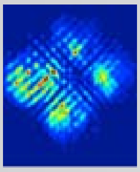
T: +61 2 6125 0361

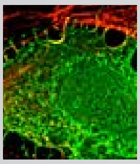
E: tim.wetherell@anu.edu.au

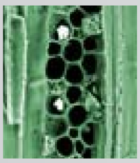
Cover image:
Gabrielle Lockett and the bee hives at the Research School of Biological Sciences, ANU.

THE AUSTRALIAN NATIONAL UNIVERSITY









http://info.anu.edu.au/mac/Media/Media_Releases/

ANU STARGAZER WINS INTERNATIONAL PRIZE

The discovery that the expansion of the Universe is accelerating has won an astronomer at The Australian National University a prestigious and lucrative international prize, the Gruber Prize for Cosmology.

Professor Brian Schmidt of the Research School of Astronomy and Astrophysics (RSAA) and his team have been announced winners of the prize by the US-based Gruber Foundation, alongside fellow astronomer Saul Perlmutter from the University of California (Berkeley).

The researchers and their teams found that the expansion of the Universe was accelerating, contrary to what astronomers had previously believed. It was thought that as the Universe expanded, the gravity of matter would slow the cosmic expansion. But, instead, measuring the distances to exploding stars more than 5 billion light years away, they found the opposite – the Universe was getting bigger, faster.

LIZARDS' FEISTY FLICKING CHANGED BY MOTION NOISE

Animals that alter their movement-based signals to overcome visually 'noisy' environments could lead to a better understanding of vision systems and improve the capacity of 'seeing' machines, according to scientists from The Australian National University.

Dr Richard Peters from the Research School of Biological Sciences (RSBS) at ANU led a research team that demonstrated for the first time how animals that rely on motion signals to communicate will alter their behaviour in relation to other moving things in their surroundings. The results are published in the latest edition of Current Biology.

The Editor's Corner - Big Bangs and Little Wiggles

Dr Tim Wetherell

It wasn't too long ago (well in my mind anyway) that I was in my first year astronomy class listening to a cosmologist discuss various scenarios for what would ultimately happen to the expanding universe. Would it slow down and re contract or would it slow down a bit but not enough to stop it expanding for ever? One thing definitely not on the menu was a scenario where the universe's expansion would accelerate. There was no reason at the time to suppose it should or even could. And yet, according to the latest research, (see above) that's exactly what it's doing.

It's important to remember that in science we deal with models and theories, not unquestionable facts and ideas. One of science's great strengths is it's ability to constantly question and test itself.

I'd like to be able to say that in my many years in science I'd never seen anyone adhere to a pet theory in the face of overwhelming contradictory evidence, but in truth I can't. Scientists are human after all. But what I can say without any doubt is that science is a lot better at such self questioning and far more objective that any other field of human endeavour I've ever been involved in.

For this reason, It's especially nice to see an almost century old theory from solid state physics, Bolch oscillations, finally directly observed in the laboratory. The little oscillations of electrons in a lattice aren't perhaps quite so grandiose as the expanding universe but in a technological sense they are vital. Solid state physics underpins all electronic devices, and understanding it is the key to everything from faster computers to walking robots.

It's not that anybody really doubted Bloch's theory, the indirect effects are incredibly well documented. A direct observation is just the icing on the cake.

See page 6

The world's first transistor in 1947. Not much to look at but with a few of billion of them in every computer, don't you wish you owned the patent!

Reflections of a Summer Scholar

Gabrielle Lockett

December 2006

I'm from Otago University (Dunedin, NZ). My major is genetics, though I dabbled in bioethics, law and Asian studies and found those fascinating too. I have just finished the 4th year of my BSc (Hons), where I gained 1st class honours.

I heard about the summer scholarship program through Otago. Summer scholarships in general seem a good opportunity to keep one's mind on science over the holidays, but the ANU one stood out as offering so much - work at a prestigious university, not to mention free board, food and flights! I also have a good friend in Canberra, which ameliorated any worries about being in a new country.

I hope to gain an appreciation of Canberra and the ANU from this summer scholarship, which in part I think I have already achieved. I also hoped to learn as many new lab skills as possible, and I have already learnt so much!

My project is on behaviour in the honey bee, and exploring the neural mechanisms of reward processing. The project assesses addiction behaviour, using cocaine. The honey bee offers a unique opportunity to study addiction behaviour outside conventional model organisms (such as the mouse), as bees have a symbolic dance language. Bees use this dance language to report how valuable a resource is - and so provide a way to gauge fluctuations in their opinions of resource value.

I have spent a large part of my spare time socialising with other scholars. Burgmann also offers activities almost daily, and I've participated in heaps of these, including touch rugby (where the kiwis score most of the points, of course), volleyball, dodgeball, and pool.

It's so nice to be in a place with so many great minds!

My career aspirations are definitely academic. I have an innate curiosity and a love of learning, and am sure this would extend into scientific research. Having just finished my Honours degree, a PhD is the next step, though I would need a topic by which I was captivated.

To those considering applying for future summer scholarships, I would say definitely do it! If not solely for the academic experience, then certainly for the social aspect at Burgmann. The fact that some scholars have come back for another summer really says it all.

Gabrielle's Summer Scholar project was on behaviour in the honey bee, exploring the neural mechanisms of reward processing. The project assessed addiction behaviour, using cocaine. The honey bee offers a unique opportunity to study addiction behaviour outside conventional model organisms (such as the mouse), as bees have a symbolic dance language. Bees use this dance language to report how valuable a resource is - and so provide a way to gauge fluctuations in their opinions of resource value.

Summer Scholarships

An ANU Summer Research Scholarship provides promising undergraduate students the experience of research work. It's a valuable opportunity for students considering undertaking postgraduate research towards a higher degree.

The scholarships run for between eight weeks and eleven weeks. The period of the scholarship is broken into two parts to allow for the Christmas period when the University is closed.

Students currently enrolled in an undergraduate degree in an Australian or New Zealand University and who are completing their third or fourth year of an honours degree are eligible to apply.

cos.anu.edu.au for details

A Taste for Learning:

Cognitive enhancement in honey bees

Tim Wetherell

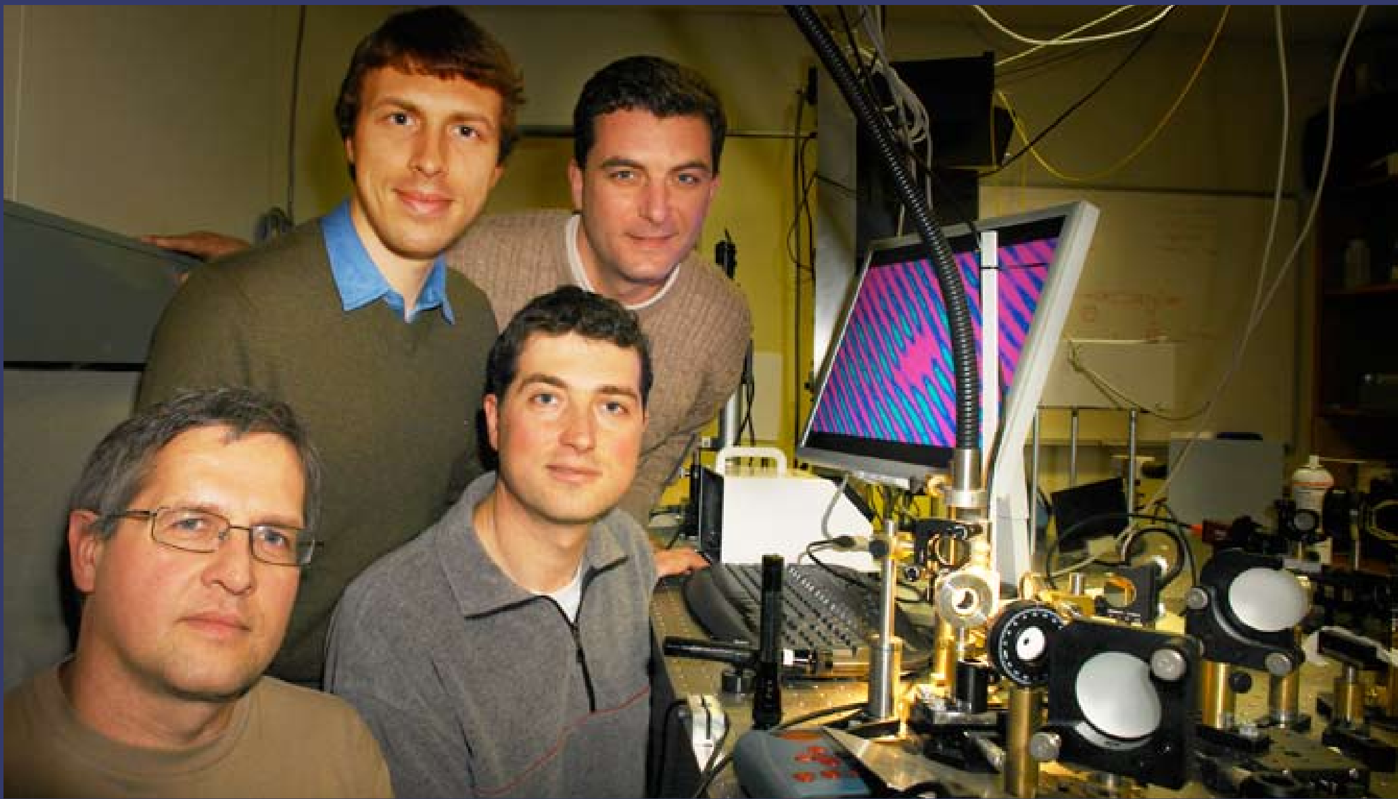
Building on the experience gained during her summer scholarship, Gabrielle Lockett is currently undertaking a PhD in the Research School of Biological Sciences. Her research focuses on methods for cognitive enhancement in honey bees. She explains "Bee brains are relatively simple, compared to those in mammals. If we can understand learning and memory processes in bees, then this could pave the way for up scaling the knowledge to complex systems like humans." Memory and cognition in bees is also interesting from a perspective of evolution. Insects and mammals have a distant common ancestry and a better understanding of the similarities and differences between cognition in the two groups might lead to insight into how learning and memory evolved.

Even though bees may be some of the most communicative insects, objectively evaluating cognitive processes can be quite difficult and requires careful experimental planning. The technique Gabrielle is currently employing is called the proboscis extension reflex assay. A bee's antennae are sensitive to both taste and smell. Applying a drop of sugar solution to the antennae will generally cause the bee to extend its proboscis to feed. If the sugar taste is accompanied by a distinctive scent the bee can learn to extend its proboscis in response to the scent alone – a Pavlovian response. Using this technique as an evaluation of the bee's ability to learn, Gabrielle experiments with different stimulant substances.

She is also looking at the molecular changes that accompany these differences in learning and memory. To do this, she looks at which genes are used (transcribed) more after dosing the bee with the drug, using microarrays. Microarrays are the DNA from over 14,000 honey bee genes spotted onto a microscope slide, to which cRNA from two samples is hybridised. After imaging (photographing) these tiny spots, Gabrielle can see which genes have increased and decreased levels of expression in bees treated with the drug. From this, she will be able to focus on genes that show interesting changes. It's early days for Gabrielle's research at present, so no one's making guesses as to which genes these will be – as always, the only way to know for sure is to do the research.

First Observation of 2D Bloch Oscillations

- Tim Wetherell



Some members of the research group L to R: Wiesiek Krolikowski, Andrey Sukhorukov, Dragomir Neshev and Anton Desyatnikov

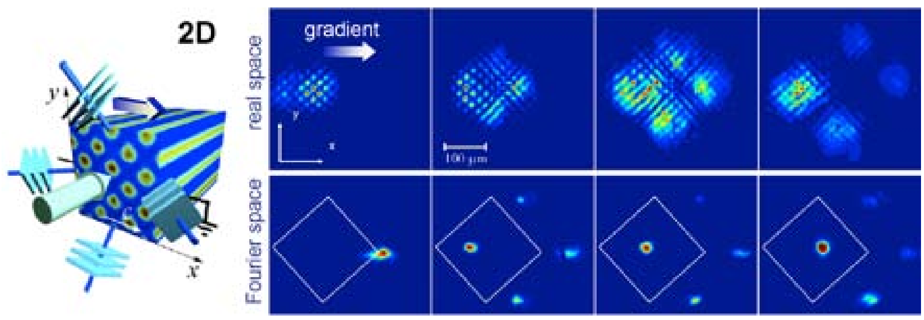
Some important scientific theories have become established and accepted by indirect observation of phenomena they create, because the underlying fundamental process can't itself be directly observed. For example planets orbiting distant stars are detected by the star's wobble not by direct observation of the planet. Whilst undoubtedly of great value to science, such indirect observations are often not just quite as exciting as the first actual photograph of such a planet promises to be.

In a similar way the phenomena of Bloch oscillations and Zener tunnelling, theoretically predicted in the 1920s, are now a firmly established part of our understanding of solid state physics despite the fact that until now, no one has been able to directly observe them.

Bloch oscillations are phenomena experienced by electrons moving through a periodic lattice under the action of an external force. A perfect example of this is the flow of an electric current through silicon when a voltage is applied. If the same electrons were flowing through space under the influence of the same voltage they would simply accelerate and gain energy in a uniform manner. However the presence of a regular pattern of potential dips and humps created by atoms of the crystal lattice leads to some interesting phenomena.

There are some energy values the electron can't have because of resonance with the lattice. These forbidden energies lie within what physicists call band gaps. As the energy of accelerating electrons approaches the gap edge, they are strongly back scattered by the lattice. Such acceleration and back scattering causes electrons to wobble back and forth in space, an effect called Bloch oscillations. Of course if moving electrons are backscattered in this way and just wobble back and forth one might ask how conduction is possible at all? The answer lies in Zener tunnelling. Some electrons are able to quantum tunnel across band gaps, thus enabling overall movement.

Understanding the basic building blocks of solid state physics, including Bloch oscillations and Zener tunnelling, enables us to build computers, mobile phones and every other modern device. Despite this,



Left: Optically induced two-dimensional lattice in a biased photorefractive crystal with optically imposed index gradient. Right: Real and Fourier space of the output beam monitoring different stages of a Bloch oscillations. The white square depicts the first Brillouin zone. The light inside the square is the oscillating part, while the three parts outside are tunnelled radiation. The arrows indicate the direction of the index gradient.

until now there has been no direct observation of either phenomena because it is impossible to directly observe the motion of individual electrons in a lattice. However, in a collaborative effort between ANU and the University of Jena, a group of researchers have recently become the first scientists in the world to directly observe Bloch oscillations and Zener tunnelling in two dimensional structures by employing nonlinear optics and a bit of lateral thinking.

Essentially their idea was that since you can't observe electrons in an atomic lattice why not look at photons in an optical lattice? Wave particle duality is one of the basic postulates of quantum mechanics and it tells us that any particle can behave like a wave and visa versa. So the physics and mathematics that describe electrons in a periodic potential are similar to those describing light in an optical potential. However, unlike electrons, it is possible to make direct measurements of both the spatial distribution and momentum of light emerging from a lattice. The latter measurement is vitally important, because the momentum of propagating waves/particles is what governs how they interact with the lattice they are moving through. One of the nice features of optics is that a simple spherical lens produces a Fourier transform of a wave profile forming an image of the momentum distribution of that wave.

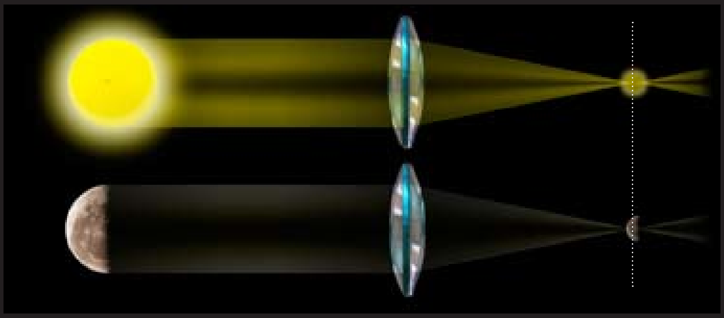
The researchers created a two dimensional optical lattice by generating a stationary laser interference pattern in a nonlinear material. The pattern of bright and dark spots modifies the local optical properties of the material inducing a regular series of regions with high and low refractive index. This means that a light beam passing through the material can experience a periodic lattice of a very similar type to that experienced by electrons passing through the regular rows of atoms in a crystal such as silicon. The nonlinear nature of the optical material also enabled the scientists to generate the equivalent of the voltage difference across a crystal needed to generate Bloch oscillations. By superimposing a smooth intensity gradient on the interference pattern used to generate the lattice, they were able to create a refractive index gradient which in effect, accelerates light in a similar way to electrons in a potential difference.

As expected, the results confirm the long established theories of Bloch and Zener. However, they also reveal many interesting and surprising complexities that arise from the lattices of higher dimensions.

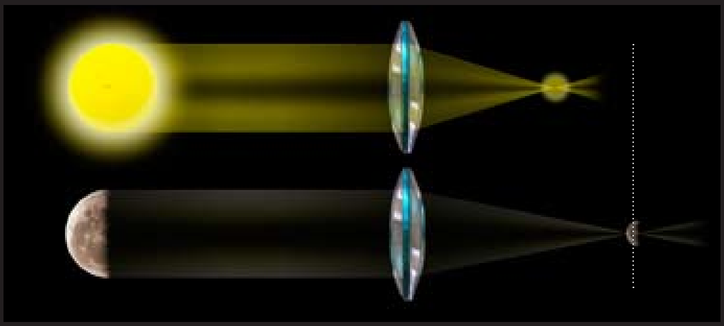
WHAT ARE NONLINEAR OPTICAL MATERIALS?

The refractive index of a material is a measure of its ability to bend light. Glass has a larger refractive index than air so light passing from air to glass is bent. If the glass is correctly shaped, this phenomena enables us to create a lens that will focus a sharp image of a distant object such as the sun or moon.

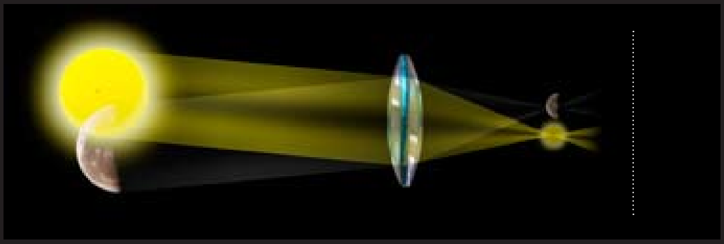
With normal linear materials such as those magnifying glasses and camera lenses are made of, the amount of bending, and thus the focal point, is the same regardless of the intensity of the light passing through them. So an image of the bright sun and far dimmer moon both come to a focus at the same point.



However with a nonlinear optical material, intense light alters the refractive index and thus the focusing properties of the lens. This means that the brighter light of the sun would alter the properties of the lens as it passed through thus coming to a different focus to that of dim moon light.



If it were possible to image the sun and moon at the same time through the same nonlinear lens, both objects would come to focus at the same shorter point. The bright sunlight modifies the path of the dim moonlight passing through at the same time. Scientists can use this principle to change the direction of a dim laser beam passing through a nonlinear medium using a much brighter steering laser. The steering laser changes the local conditions and thus the path of the dimmer beam.



As always, there are many complications to this process. Real world nonlinear materials don't exhibit the ideal behaviour of the lenses here. They have a large linear and much smaller nonlinear component mixed together in their refractive index. Their nonlinear properties also usually have a strong directional dependence and vary with the polarization of the light. However, the basic underlying principle remains exactly the same.

Unravelling Ttyh1's Role

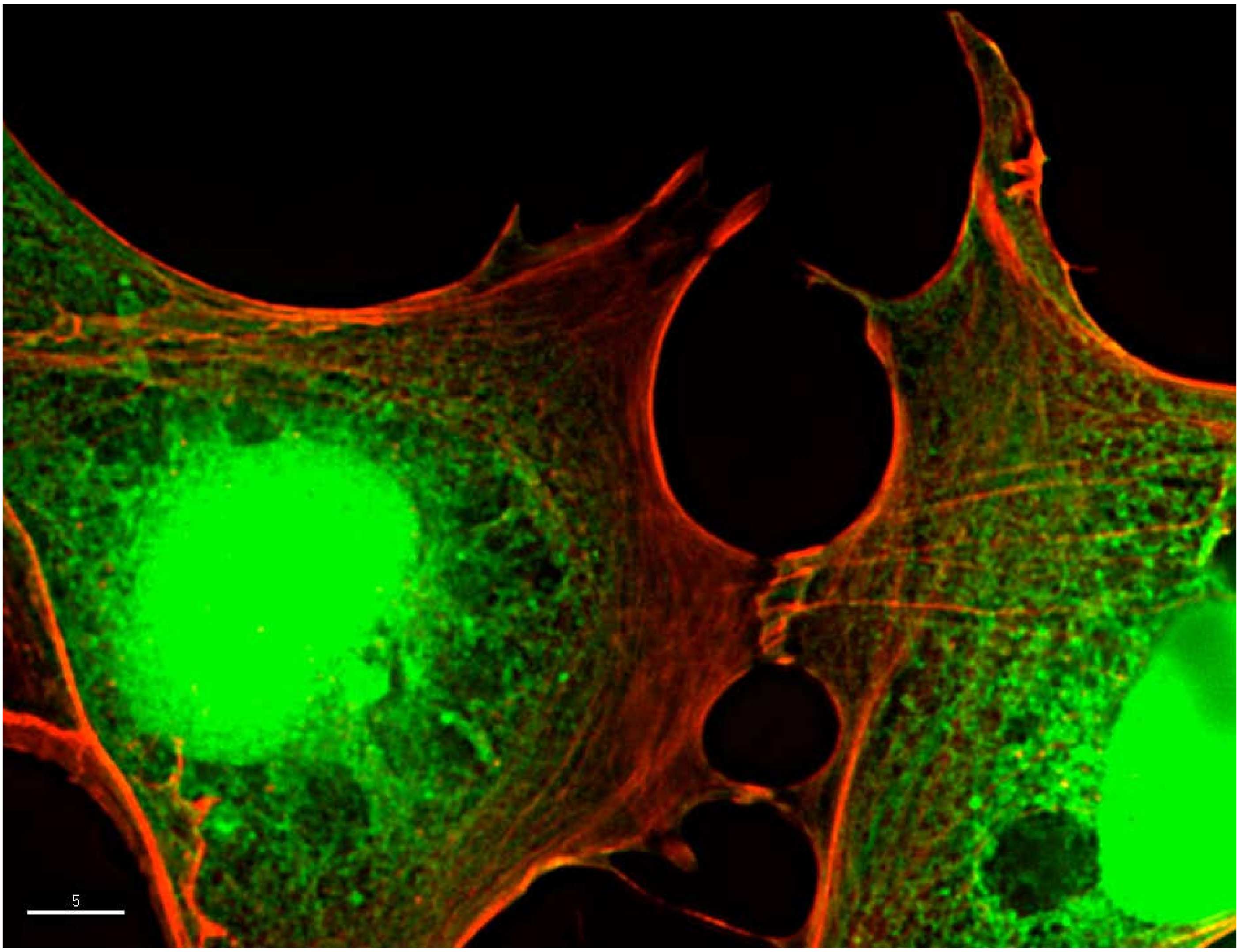
What a difference a gene makes

- David Salt

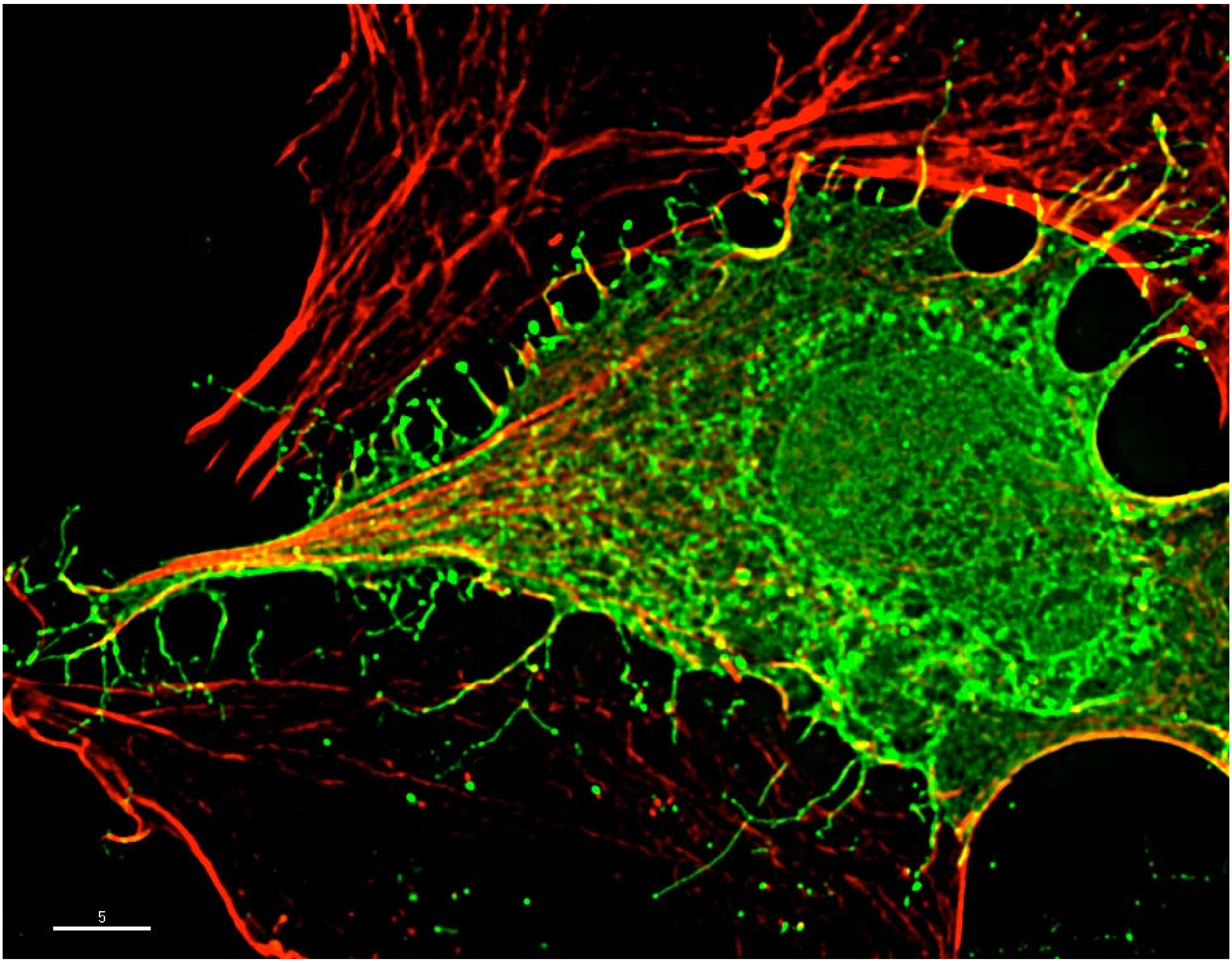
Each of our cells carries a complete set of genes, but most of the time the majority of these genes are switched off. This is because there are many different cell types that make up our body and each cell type uses a different subset of genes in order to perform its function. For example, brain cells and liver cells are very different in appearance and behaviour, and employ different combinations of genes to achieve their specific functions.

Genetic manipulations can sometimes be used to understand how a gene functions. Essentially, a gene can be expressed in a specific cell type which is easy to culture, and often in cells where the gene normally switched off. Scientists can observe what happens by either turning a gene off, or over-expressing it. By comparing cells in which a gene of interest is expressed with normal cells of the same type (where the gene remains switched off), it's possible to find clues about what the unknown gene does. The technique is called ectopic gene expression and Clay Matthews, a PhD student in the Molecular Genetics and Evolution group at the Research School of Biological Sciences, used this method to better understand a mammalian brain gene known as Ttyh1 (a human homologue of the fruit fly, Drosophila melanogaster, tweety gene).

As with all genes, the Ttyh1 DNA sequence exists in all of our cells but the Ttyh1 protein is only expressed in some brain cells. To determine the function of the gene, Mr Matthews modified the Ttyh1 gene so that it was fused to a small green fluorescent protein (GFP) and could be expressed in cultures of epithelial kidney cells. To observe what happened, he exposed the Ttyh1-GFP expressing cells



Normally the kidney cells are semi-rounded with a few angular regions as shown here.



The expression of the Ttyh1 gene had a dramatic effect on the shape and structure of the actin cytoskeleton in kidney cells. When Ttyh1 was ectopically expressed, the cells made contacts with other nearby cells and the substrate via long membrane protrusions that led to the cell membrane being literally torn apart as the cell moved.

to a specific wavelength of light which allowed the dynamics of the Ttyh1 protein to be observed (a control line of cells was also grown expressing just the GFP gene to ensure that any changes observed were not due to the GFP gene itself).

And what happened? The expression of this one gene had a dramatic effect on the shape and structure of the cell's actin cytoskeleton. The cells began making contact with the underlying substrate and other nearby cells, and forming attachments via long Ttyh1-induced membrane protrusions. Normally the kidney cells are semi-rounded with a few angular regions – similar to the shape of Australia – but when Ttyh1 was expressed in these cells, long projections grew out from the cell surface. As these projections made contact with other cells or the underlying surface, they formed strong adhesive contacts and when cells moved forward by a process called cell migration, the projections remained bound to the underlying surfaces and surrounding cells. This led to the cell membrane being literally torn apart as the cell moved, and the consequent formation of deposits of the Ttyh1 protein remaining attached to the underlying surface and surrounding cells.

"This finding directed us to conduct research into the possible involvement of Ttyh1 in cell adhesion and cell migration," says Clay Matthews. "Since that initial discovery we've been able to show that Ttyh1 is closely associated with other known cell adhesion molecules such as integrin, which can affect the cell shape by activating signaling cascades which eventually lead to the alteration of the cytoskeleton. The expression of Ttyh1-GFP in these cells led to a significant increase in the rate of cell migration".

"Taken together with information from other experiments, these findings may show that the Ttyh1 protein is a new adhesion molecule in the mammalian brain. Adhesion molecules are important therapeutic targets as they are essential during processes such as development, wound healing and neuronal synapse formation."

The results may also prove to be useful during the development of new technologies that require neurons (specialised brain cells) to attach to inorganic substrates such as in nano-scale printed circuit boards. Mr. Matthews is currently in discussions with researchers at the University of Adelaide and Nippon Telecom (Japan) about how to further develop these findings and other cell-substrate adhesion related projects.

A Tale of Three Timbers

- David Salt

During his professional life as a microscopist at the ANU Electron Microscope Unit Dr Roger Heady recorded thousands of scanning electron micrographs on a diverse array of topics. Now he's a Visiting Fellow at the Fenner School of Environment and Society and sorting through his vast collection of images to catalogue them and pick out some of his more interesting images for anyone interested.

While he's captured aspects of everything from beer bubbles to mineral crystals under the scanning electron microscope, Dr Heady's first love has always been the structure of wood and timber. So, as an example of some of his work, here are three stories and images of very different types of wood.

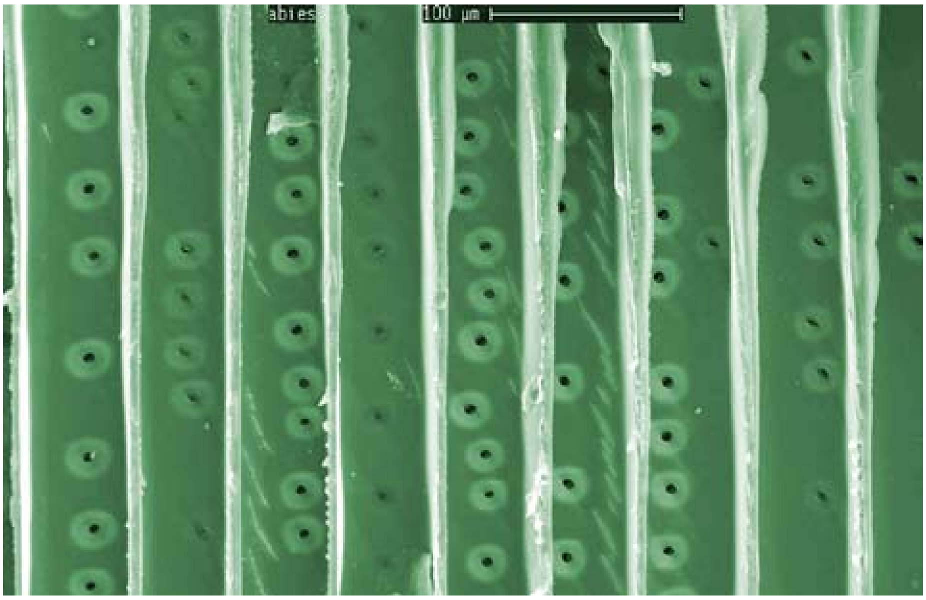
The timber from the tree Ochroma lagopus is light, easily cut and glued. You're more likely to know it as balsa wood.

"The word 'balsa' is Spanish," says Dr Heady. "It means 'raft', and it refers to its excellent floatation qualities. Although one of the lightest woods in the world, balsa is technically a 'hardwood' since the trees belong to the angiosperm, not gymnosperm, group. Balsa wood has an air dry density of only 120 Kg/m3 whereas oak is 700 Kg/m3.

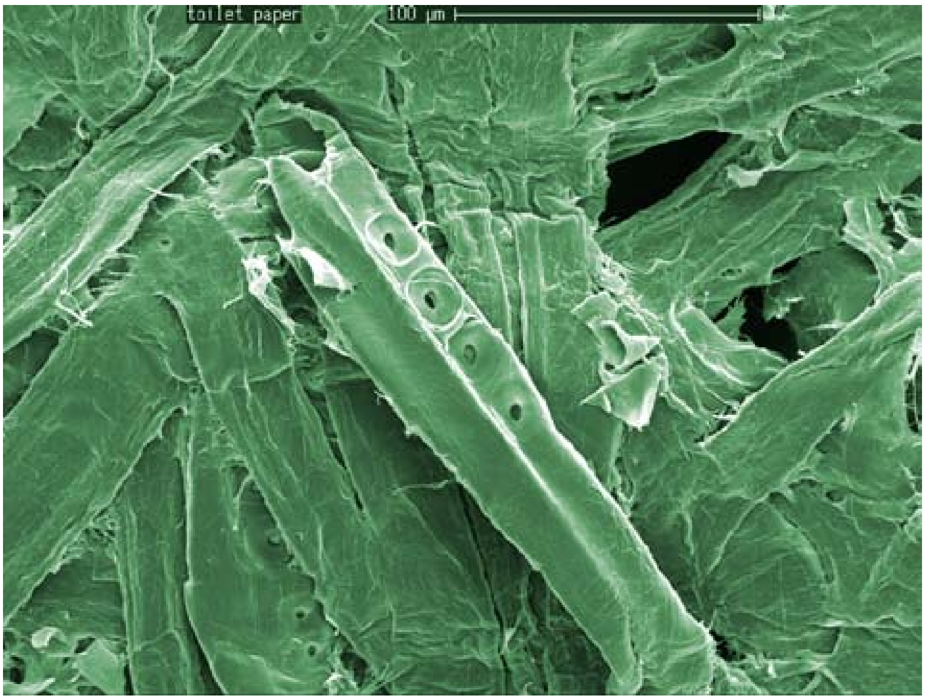
"Balsa wood's cells are big and very thin-walled, so that the ratio of solid matter to open space is very small. Only about 40% of the volume of the wood is solid substance. Balsa trees grow in the humid rain forests of Central and South America. To give the balsa tree the strength to stand, each cell of the wood is full of water, thus making them rigid – like a car tyre full of air. Green balsa wood contains five times as much water weight as it has actual wood substance, whereas most hardwoods contain little water in relation to wood substance. Green balsa wood must therefore be carefully kiln-dried to remove most of the water before it can be sold. Most Balsa wood sold in Australia is now grown in New Guinea."

The timber of Red Turpentine is used in shipbuilding and wharf decking because of its resistance to marine borers. It's said this resistance due to the presence of silica particles in its wood. Wood of the Queensland walnut also contains silica particles which tend to blunt saws, planes, and other hand-tools used to cut them.

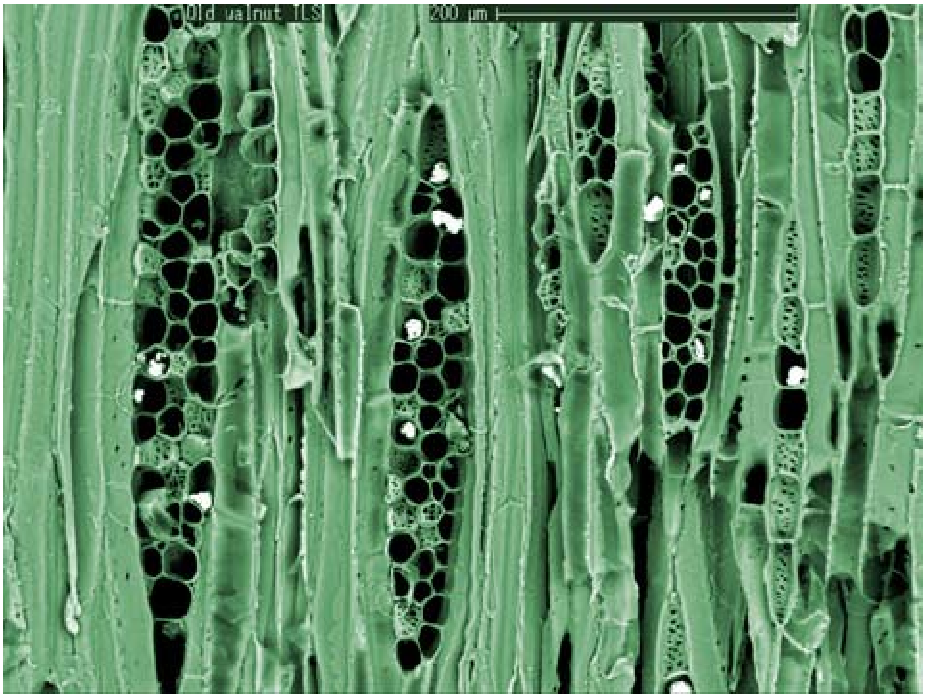
"By imaging Queensland walnut in the 'back-scattered-electron' (BSE) mode, it's easy to pick out these silica particles," explains Dr Heady. "The BSE mode shows differences in the elemental composition of the sample. Elements with a higher atomic number appear brighter because they have bigger atomic nuclei and so reflect more electrons. Silicon has a higher atomic number than the carbon and oxygen of the wood so it appears bright and easily seen against the wood background."



A longitudinal view of nine tracheids on the edge of a wood block of pine wood showing the many bordered pits.



Magnified view of toilet paper. The 'fibre' which can be readily identified as a softwood tracheid due to the presence of four bordered pits.



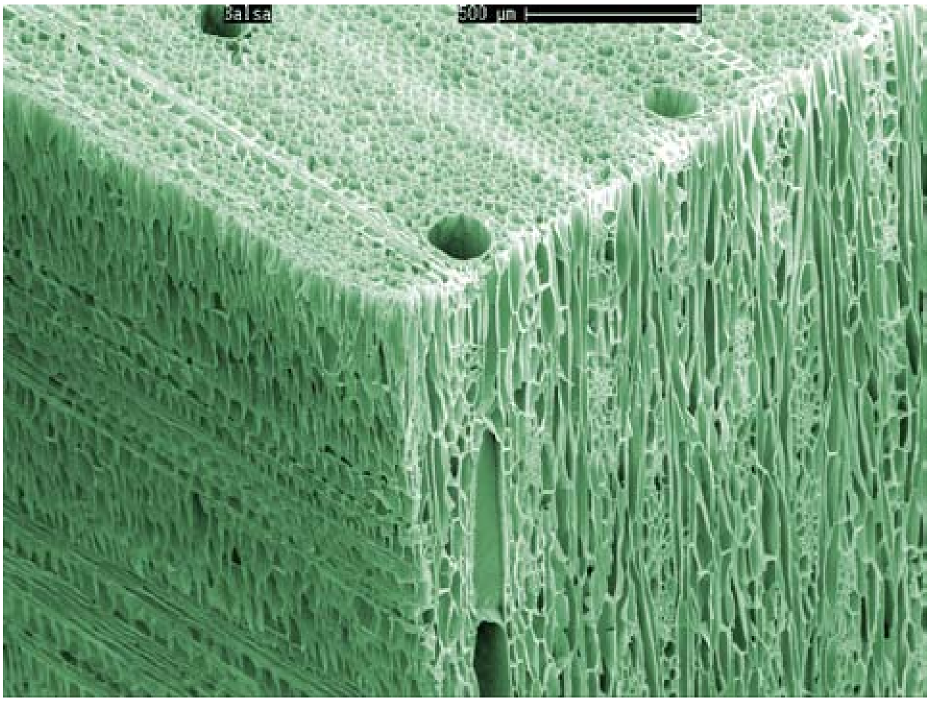
A tangential longitudinal view of a walnut wood block showing silica particles in the rays.

Toilet paper consists of a mat of randomly inter-woven fibres that are formed into a thin flat sheet. The 'fibres' are almost always obtained from wood pulp, and the type of wood used is softwood (wood from a conifer tree) – most likely Pinus radiata or other plantation-grown softwood.

In relation to toilet paper making,

"When it comes to toilet paper, the term 'fibre' is a misnomer since fibres only occur in hardwoods, not in softwoods," comments Dr Heady. "Softwood toilet paper fibres are actually tracheids – tubes 20 µm in diameter and about 2-3 mm long that comprise the xylem of the conifer tree. They conduct water up the tree.

"Tracheids are interconnected to each other by apertures called bordered pits. In the process of paper-making tracheids are separated from each other and flattened into a sheet. However, the bordered pits present in the treated tracheids can often still be observed in the SEM image."



The corner of a block of balsa wood. Note how thin-walled the cells are.

THE AUSTRALIAN NATIONAL UNIVERSITY

ScienceWise is published by the
ANU College of Science
Editor: Dr Tim Wetherell

Subscription

Subscription to ScienceWise is free to schools, if you would like to be added to our lists please visit

http://sciencewise.anu.edu.au

ANU COLLEGE OF SCIENCE
CoS@anu.edu.au
http://cos.anu.edu.au

CRICOS Provider No.00120C

ScienceWise offsets its paper consumption with contributions to native tree planting programs.