Magazine of the ANU COLLEGE of SCIENCE

Volume IV No. III

SCIENCE WISE

THE AUSTRALIAN NATIONAL UNIVERSITY

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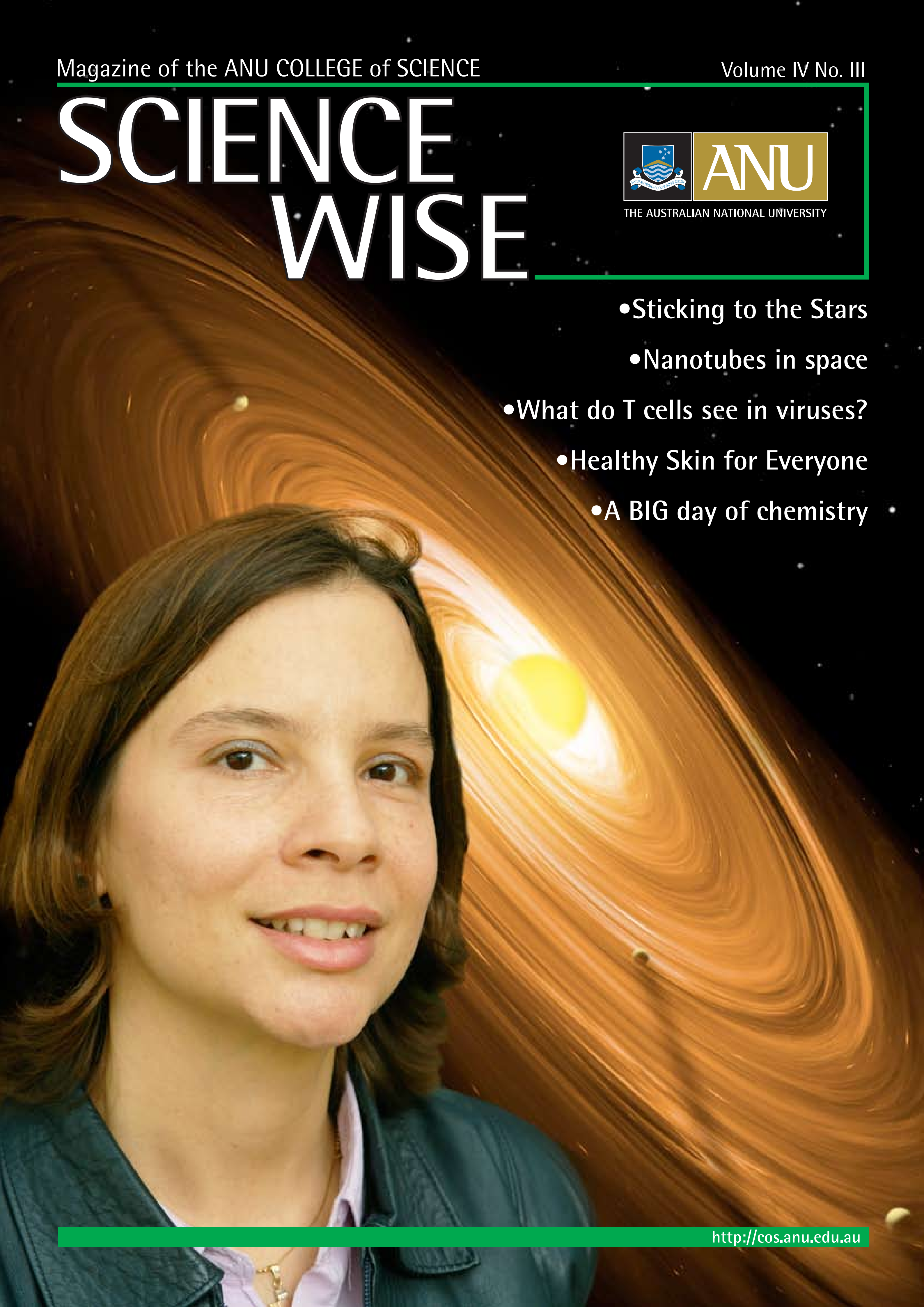

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SCIENCE WISE

Magazine of the ANU COLLEGE OF SCIENCE

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Cover image:
Dr Raquel Salmeron with an artist's impression of an accretion disc.

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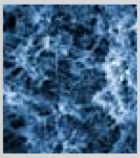

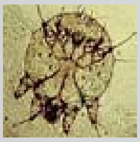

GRANT FOR SOLAR ENERGY STORAGE SYSTEM

The first large scale working demonstration of a solar energy storage system based on research undertaken at The Australian National University will be developed thanks to a $7 million grant from the Commonwealth Government.

The system uses ammonia-based thermochemical solar energy storage and is intended for use with 'Big Dish' solar concentrators. The prototype Big Dish, located on the ANU campus, is the world's biggest dish solar concentrator, with an aperture area of 400m^2.

The technology was developed by Dr Keith Lovegrove and colleagues at the ANU, and is being commercialised by Canberra company Wizard Power. Wizard Power has received the grant from the Australian Greenhouse Office to build a commercial scale demonstration of the storage system.

NEW ALLIANCE TO SPEARHEAD LEADERSHIP ON CLIMATE CHANGE RESEARCH

Three of Australia's top universities have formed an alliance to spearhead national leadership in climate change research, education and policy.

Comprising UNSW, The Australian National University and Monash University, the Universities Climate Consortium (UCC) builds on three years of collaborative work and consolidates a significant grouping of strategic skills, resources and institutional investment on climate-related issues.

The Consortium is the Australian equivalent to the US University Corporation for Atmospheric Research, a non-profit consortium of national and international university members.

THE EDITOR'S CORNER – NEW PLANETS AND THE FUNDAMENTAL SCIENCES

Back in 1781 William Herschel, at the eyepiece of his home made telescope made the chance discovery of the planet Uranus. It was the astronomy story of the century, the first new planet discovered since the beginning of recorded history. The shock would be something like the discovery of a previously unknown continent on earth today. With the discovery of Uranus, the boundaries of our own solar system had suddenly expanded.

However, in the following century astronomers noticed that Uranus wasn't following the orbit they expected. Two mathematicians, John Couch Adams and Urbain Jean Joseph Leverrier independently calculated that the deviations in the orbit of Uranus were due to another massive and more distant planet. The complexity of the mathematical effort performed by hand with pencil and paper over months and years defies belief in our modern computer age. But with their herculean efforts, Adams and Leverrier had discovered a new planet without ever looking through a telescope and in the process, given astronomers the foundations of modern extra-solar planet discovery.

Modern astronomers are especially interested in finding earth-like planets beyond our own solar system because of the implications for extraterrestrial life. No current generation telescope is capable of visually resolving such planets but one thing astronomers can do is monitor the microscopic wobble an orbiting planet causes on either the position or spectrum of its central star. The rest comes down to gravity, physics and complex mathematical, calculations. Modern planet hunting, such as the recent discovery of an earth-like planet Gliese 581 C orbiting a red dwarf star within our own galaxy, is a perfect example of theory, experiment, maths and engineering coming together to achieve great things in science.

Much of modern astronomy is like this, complex theoretical models compared to careful measurements of observable parameters coming together to create a picture of something which is in itself completely invisible - such as distant planets or the accretion discs they form from (see page 4).

Artist's impression of Gliese 581 C orbiting its red dwarf sun

Sticking to the Stars

The complex processes creating accretion discs

– Tim Wetherell

Modern astronomers believe that stars are born in the dense cores of molecular clouds, essentially regions of space with relatively high density gas and dust, such as those in the the famous Orion nebula. Within such nebulae, the interplay between turbulent flow, magnetic fields and shock waves from nearby supernovae explosions may result in the formation of a region with slightly higher density than the surrounding medium. This dense region then begins to gravitationally draw material from the cloud in a process astronomers call accretion. However the process is far more complex than it might at first sight, appear.

The individual particles in the cloud are all moving and the cloud generally has a net angular momentum. The laws of physics dictate that this angular momentum must be conserved which means that as material is drawn towards the forming protostar, it spins faster and faster like water flowing down a plug hole. It also means that the inflow occurs preferentially in the direction perpendicular to the plane of rotation, so the inwardly spiralling material forms a flattened disk with the protostar at the centre. However, there comes a point where the speed of rotation within the disk is so fast that centrifugal force prevents any further inward motion and the disc becomes rotationally supported. This is exactly the situation with all bodies in stable orbits including our own planet. The Earth is unable to move closer to the sun without shedding some of its angular momentum and fortunately for us, it has no way to do this. But it is exactly this kind of orbital stability that nature has to overcome if stars such as the sun are to form in the first place. How this is possible within physics of accretion disks is a question of special interest to Dr Raquel Salmeron of the ANU Research School of Astronomy and Astrophysics and Research School of Earth Sciences. Dr Salmeron is developing a novel theoretical model of accretion that incorporates a more comprehensive range of processes than has previously been used. Dr Salmeron explains that angular momentum lies at the core of disk dynamics and in order to understand angular momentum transport it is essential to look closely at the microphysics, in other words, at the detailed dynamical processes in the gas and the interaction of the gas with the magnetic field.

A very small number of the atoms in the accretion disk surrounding a protostar are ionised by interstellar cosmic rays or radiation from the central object and/or a nearby star. The motion of these charged particles (ions and electrons) leads to the generation of magnetic fields which in turn influence the paths of the charged particles themselves. The process is immensely complex and far from well understood, but astronomers know the disc to be weakly magnetised. Furthermore, collisions between ions and neutral atoms also cause indirect linkage between neutral atoms and the magnetic field. Dr Salmeron believes that understanding and accurately modelling these interactions is the key to answering fundamental questions about the physics of accretion.

Depending on the density of the gas and the number of charged particles within it there are different kinds of diffusion processes (essentially the `slippage' between the neutral gas and the magnetic field) that can occur. Two of them, in particular, have formed the basis for existing theoretical models. In very low density regions the charged ions and electrons can move with

Artists impression of an accretion disk forming a protostar and planets

Hubble Space Telescope view of the great nebula in Orion, a region of stellar formation - Image NASA

the magnetic field lines without much interaction with the surrounding neutral atoms because they hardly ever run into them - the so called ambipolar diffusion process. On the contrary, when the gas density is very high, they collide with neutrals so frequently that this process dominates their behaviour - the Ohmic diffusion limit.

Dr Salmeron's own research focuses on incorporating a third and largely neglected diffusion process, Hall diffusion. This occurs at intermediate densities where the small, fast electrons are able to follow field lines relatively freely whilst the much larger ions experience multiple collisions with neutrals. It's rather like the way an army of ants can move through a heard of elephants without bumping into too many of them, where as two herds of elephants simply can't cross paths without mayhem resulting. According to Dr Salmeron all three diffusion processes are often at work in different regions within a stellar accretion disk, and that it is the interplay of these processes, driven by the magnetic field, that dictates the overall behaviour of the system.

The complex picture that emerges is of a swirling disk of matter surrounding a protostar, gradually offloading a large proportion of its angular momentum through complex ion/ magnetic field interactions and collisions with neutral atoms. This leads to a small amount of disk matter moving outwards and carrying away the excess angular momentum, so that most of the mass can slow down and spiral inwards towards the forming star. Depending on the magnetic field strength, the matter can move radially out, like water spun out of washing, or can be ejected vertically in what is known as disk wind. One interesting feature of disk wind is that the ejected material often forms what are known as jets - intense energetic flows of matter at right angles to the system.

Astronomers can observe such disks and jets in some nearby forming stars but with current technology telescopes, resolving the details of the process is tantalizingly out of reach. Dr Salmeron hopes that completion of new generation instruments such as the Atacama Large Millimetre Array under construction in Chile may provide the observational data required to test and refine current accretion theories.

The accretion process underlies all star and planet formation in the universe and determines how matter enters black holes such as those believed to lie at the centre of many galaxies. Consequently, understanding accretion is one of the fundamental topics in astronomy today.

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Nanotubes in space – David Salt

Building multifunctional walls for spacecraft

If humans are ever to travel through deep space they'll need protection against the hazards of space radiation associated with solar flares and cosmic rays. To protect their precious human cargo, spacecraft will need special shields incorporating materials consisting of the lighter elements such as hydrogen, boron, and lithium. However, additional shielding comes at a significant price in the form of extra weight, more fuel and increased flight costs.

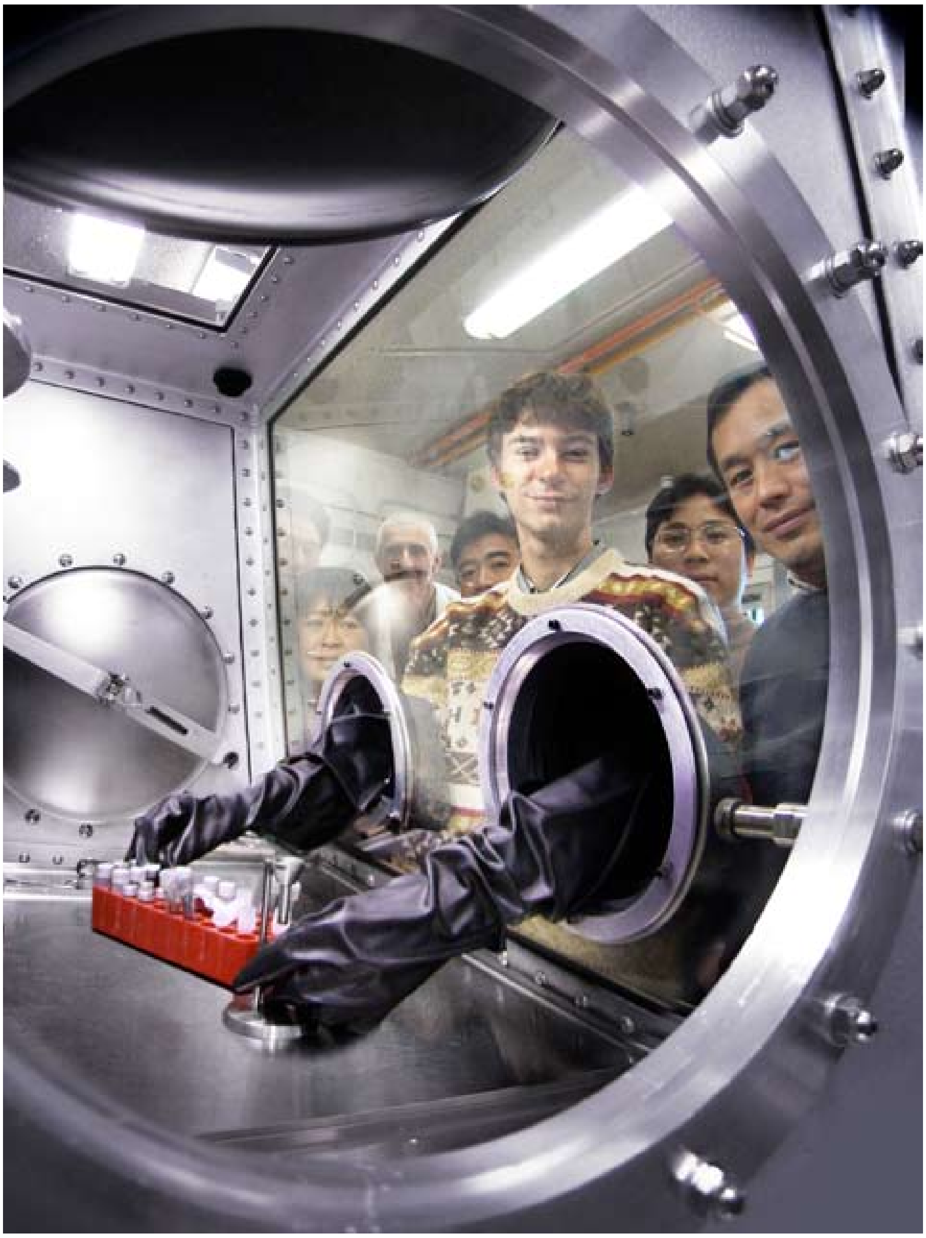
In order to maintain low weight while increasing safety, reliability, and functionality, many scientists are suggesting that the body of future spacecraft will need to simultaneously serve multiple functions. In other words, the body will need to provide structural integrity, effective shielding, energy storage and carry an array of sensors.

What material or mix of materials could serve so many different functions? A blend of carbon nanotubes is one future material under consideration because of it's light weight, excellent mechanical properties and it's capacity to store energy. Now researchers from the Department of Electronic Materials Engineering (RSPSE) are proposing a variation on this theme – isotopically enriched boron nitride nanotubes.

"Isotopically enriched boron nitride nanotubes have many similar properties to carbon nanotubes," says Dr Ying Chen. "However, they also offer some important advantages as they have better radiation-shielding properties and stronger resistance to oxidation.

"By isotopically enriched we mean the boron nitride has a higher concentration of the isotope boron 10. Normally boron nitride is 80% or more composed of boron 11.

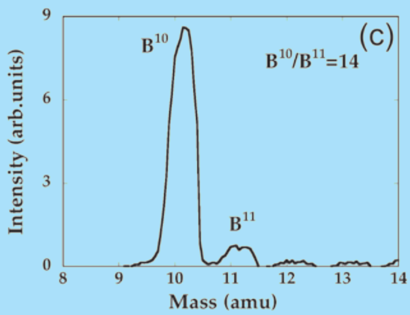
"The isotope boron 10 is an efficient neutron absorber with a very high neutron-capture cross section. Consequently it's widely used as the inner shielding layer inside nuclear reactors.



Dr Ying Chen (right) and members of the nanomaterials team load samples inside a special pressurised glove box.

"We have now demonstrated for the first time that it's possible to produce large quantities of high quality isotopically enriched boron nitride nanotubes using a ball-milling/annealing process."

Dr Chen and colleagues Mrs Jun Yu, Professor Rob Elliman and Dr Mladen Petravic have been refining the ball milling process for preparing boron nitride (BN) nanotubes for many years. It involves grinding down a powder of boron into nanoparticles in a ball mill in which steel balls tumble against each other



Secondary ion mass spectrometry of a sample of 10BN nanotube sample, showing the dominant presence of 10B over 11B.

for hundreds of hours. The fine boron material is then heated in an atmosphere of nitrogen (in the form of ammonia, NH_3).

"To produce isotopically enhanced BN nanotubes (referred to as 10BN nanotubes) you begin by grinding down a powder of the isotope boron 10 (often noted as 10B). Our analysis of the final product shows we can produce BN nanotubes with up to 96% boron 10.

"We found we could produce 10BN nanotubes with different diameters (up to 100 nm) and lengths (up to 100 µm) by varying the growth conditions and atmosphere. For example, nanotubes with a larger diameter (greater than 50 nm) can be produced by annealing at a higher temperature of 1200 °C for a longer period of time.

"The control over the nitriding reaction between the 10B and the NH_3 gas is crucial for the formation of thin, cylindrical 10BN nanotubes that contain fewer defects and exhibit stronger mechanical properties than other nanostructures. To avoid the formation of large crystals or thick, bamboo-type nanostructures through fast 3D crystalline growth, the nitriding reactions are carried out at lower temperatures. This can be achieved because of the ball-milling of the boron 10 powders."

"The 10BN nanotubes are lightweight, with a density of 1.85 g cm^{-3} and have an excellent resistance to oxidation. They exhibit a high neutron-absorption cross section because of the high content of 10B, as recently determined at ANSTO. The successful production of high yield 10BN nanotubes using a ball-milling/annealing process makes 10BN nanotube samples available in large quantities for space-radiation tests."

And there are many other potential applications for 10BN nanotubes back here on Earth. For example, there is a lot of talk about developing fusion energy to feed an energy-hungry world. One of the major challenges in developing fusion energy on a commercial basis is coming up with materials that can provide shielding from the high neutron fluxes produced by the fusion process. What will be needed is a strong, light weight, cost effective radiation shielding. 10BN nanotubes may just fit the bill.

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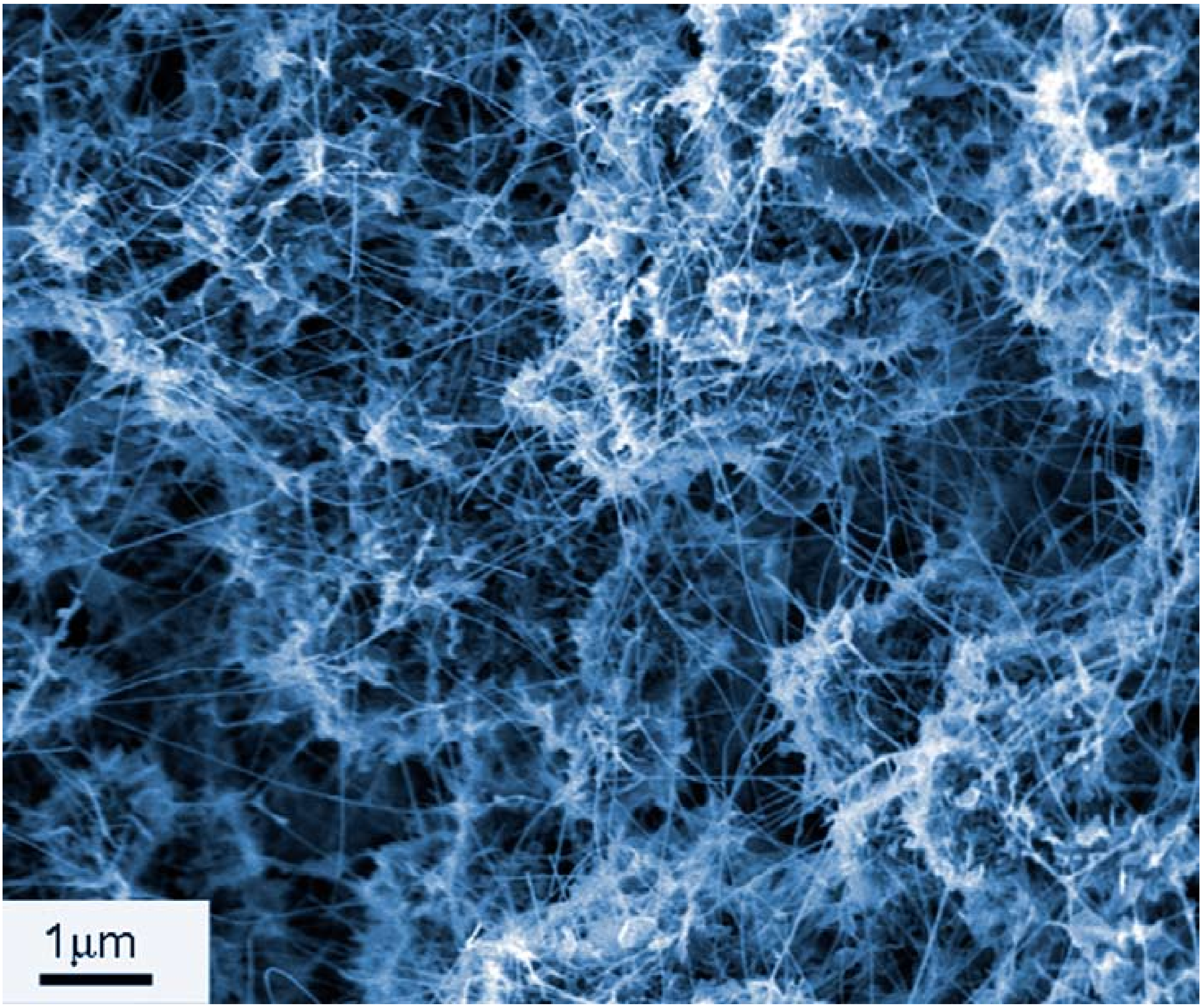


A scanning electron microscope image of the boron nitride nanotube (enriched with boron 10). They were produced by grinding a powder of the isotope boron 10 in a ball mill for many hours and then heating the crushed powder to around 1100 °C for 6 hours in an atmosphere of ammonia.

Trying to understand what T cells see in viruses?

– Tim Wetherell

The human body with its regulated temperature and rich supply of nutrients offers the perfect environment for invading microorganisms to potentially flourish, so to keep us healthy we need multiple layers of defence against them. Some of these defences are simple but effective physical barriers like the skin or mucous membranes. However when inevitably bacteria or viruses do get inside, we rely on out highly complex immune system to fight the infection. The front line troops of the immune system are lymphocytes, a class of white blood cells. There are several different types of lymphocyte in the mammalian immune system, each with a specialised role. Some work by recognising foreign proteins on the surface of cells others simply kill any cells that don't carry our own personal marker proteins.

During an infection the immune system generates millions of lymphocytes targeted to the proteins particular to a given pathogen. After the infection is destroyed, a few of these specially adapted cells remain in the body as memory cells, enabling the system to fight similar infections much more effectively second time round. It is the action of this immune memory that forms the basis for successful vaccination.

The practice of vaccination dates back to the eighteenth century physician Edward Jenner. Jenner noticed that milkmaids, who by the nature of their occupation were highly prone to a harmless illness called cowpox, almost never contracted deadly smallpox. Modern immunologists know that smallpox, cowpox and vaccinna are all derived from a common ancestor and therefore strongly interrelated. By infecting patients with cowpox, Jenner was able to dramatically reduce their chances of later developing smallpox. Two centuries of immunisation has successfully seen smallpox eradicated as a human disease and scientists have been successful in developing numerous other vaccines to a range of illnesses. Nontheless, there have always been a number of immune related diseases that have traditionally been unable to be treated in this way.

However, with the emerging science of genetic engineering, scientists are hopeful that genetically engineered versions of vaccinna may be able to fight a whole range of other diseases ranging from HIV to many types of cancer. The basic concept is that extra DNA is added to the vaccina genome which programs it to

It's all in the Blood

The bulk of the cells in mammalian blood are red cells or **erythrocytes.** These contain great quantities of haemoglobin, which gives them their red colour and have the primary purpose of carrying oxygen from the lungs to the tissues of the body.

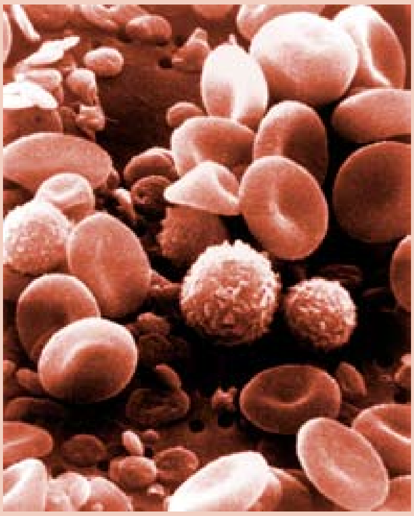
White cells are found in much lower numbers than red cells and are divided into five major groups each with a distinct function.

Neutrophils attack and destroy bacteria. Pus is composed of large numbers of "killed in action" Neutrophils.

Lymphocytes, which are sub-divided into: B cells and T cells. B cells make antibodies to immobilise pathogens in a sticky glue. Some B cells also serve to "remember" a particular antibody enabling the immune system to respond more quickly and effectively second time round. T cells in their various sub groups, co-ordinate immune response and kill virus infected and tumour cells. T cells get their name because although formed in the bone marrow, they mature in the Thymus.

Monocytes attack bacteria in a similar way to neutrophils, but in addition they also carry samples of pathogen material to T cells initiating immune response.

Basophils are responsible for histamine response related to allergy and inflammation. Inflammation can sometimes help the immune system by bringing more blood to a site of injury or infection.



Electron micrograph of human blood showing red cells (dish shaped) and a variety of characteristically irregular Lymphocytes.
Image - National Cancer Institute

Dr Tscharke and colleagues working in a sterile hood

produce additional proteins characteristic of other organisms. When the harmless vaccinna infection runs through the body, the immune system responds and builds up memory cells and thus immunity to both vaccinna and the additional "cargo" genes. However as so often is the case in science, this elegant sounding idea is a lot more difficult to accomplish in practice. The problem tends to be that the immune system's T cells are not equally sensitive to all the various foreign proteins and in some cases are not sensitive to them at all. It's still a puzzle to scientists why our T cells are only tuned to perhaps 10% of the viral proteins that might potentially be used to identify an infected cell.

Dr David Tscharke of the ANU School of Biochemistry & Molecular Biology works at the interface of virology and immunology building up an understanding of the mechanisms involved in T cell activation. Dr Tscharke and his coworkers have recently been successful in identifying all 40 of the vaccinna antigens visible to human T cells. Whilst this can't explain why the T cells only see this small subset of the vaccinna proteins, it does represent a ground breaking step in better understanding the immune response mechanism. Dr Tscharke explains that "unless you are able to monitor the immune response to the entire range of proteins, it's very difficult to eliminate guesswork from your models."

As has so often proved to be the case in science, researchers are hopeful that an improved basic understanding of the underlying mechanisms of immune response, will open the door to much improved treatments.

Quite apart from developing a better understanding of the underlying mechanisms of immune response to vaccinna, Dr Tscharke has a very practical interest in the pox family. Although small pox has been eradicated from the world, the battle between viruses and the immune system is not a static thing. A new variant of the pox virus family, Monkeypox, is being increasingly seen as an emergent disease. Monkeypox caries with it a variety of threats. In humans it can be almost as deadly as smallpox but unlike small pox, monkeypox is also carried by animals. This makes it's eradication by vaccination almost impossible. It is vitally important to understand as much as possible about pox family viruses so that future threats, such as Monkeypox can be effectively dealt with.

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Healthy Skin for Everyone

- Sophie La Vincente

Dr Sophie La Vincente talks about her experiences working with the Healthy Skin Program in remote communities

Leaving the Melbourne winter behind on frequent trips to the tropical north of Australia could justifiably be considered a perk of the job. But when such trips involve working closely with communities in East Arnhem Land to reduce the devastating consequences of skin infections and infestations, 'perk' seems an inadequate descriptor. For me, this is a rare and remarkable experience. It is a privilege to spend time in this part of Australia and get to know the Yolngu people of East Arnhem.

I am a student in the Master of Applied Epidemiology program with the National Centre for Epidemiology and Population Health (NCEPH) at ANU. My placement for this 2-year course is with the Centre for International Child Health in Melbourne; however one of my major areas of work is a collaborative project with the Menzies School of Health Research in Darwin. It is through this project, the East Arnhem Regional Healthy Skin Program, that I have had the opportunity to work in remote Aboriginal communities.

Scabies is an ectoparasitic infestation caused by the microscopic mite *Sarcoptes Scabiei* variety *hominis*. Scabies can often lead to the sufferer developing infected skin sores. Both scabies and skin sores are widespread in many Aboriginal communities in the Northern Territory, and children are particularly at risk. Recent research in the communities of East Arnhem has revealed that, in the first year of life, six out of ten children will have scabies and seven out of ten will develop skin sores.

This is problematic not only due to the local effects associated with scabies and skin infection, but because the primary bacterial pathogen underlying most skin sores in these communities is Group A *Streptococcus* (GAS), which is associated with a myriad of debilitating secondary complications, including rheumatic fever and renal disease. Scabies is thought to underlie between 50 and 70% of bacterial skin infections in these communities, so controlling scabies is critical to improving skin health and reducing the burden of these sequelae.

The East Arnhem Regional Healthy Skin Program is a community-based intervention to reduce scabies, skin sores and associated chronic diseases. In each of the six communities involved, trained local Healthy Skin workers spend time in the clinic and in peoples' homes teaching the community about skin health, checking childrens' skin and distributing treatment where required. Treatment for scabies requires total body application of permethrin cream for not only the individual with scabies, but also all household contacts. One of the key features of the Program is an annual "Healthy Skin Day" – a mass treatment day during which all community members are encouraged to use the treatment and participate in a community clean up.

Under the guidance of Dr Ross Andrews of the Menzies School of Health Research (and also a graduate of the Master of Applied Epidemiology program), and Dr Scott Cameron of NCEPH, I am evaluating the community-based scabies control model employed by the East Arnhem Regional Healthy Skin Program.

"Healthy Skin Program" community worker applying scabies treatment cream to a child

Community-based programs involving mass treatment have been extensively used to control parasitic infections, such as onchocerciasis and lymphatic filariasis, in many settings around the world. A similar approach has also been used to control scabies and skin sores in other countries, and has demonstrated success in other Aboriginal communities in Australia.

The success of such a program hinges on the treatment being acceptable to the community. My role in evaluating the acceptance and utilisation of the treatment, as well as any barriers to treatment uptake that may exist, will provide valuable quality assurance and help direct our efforts to ensure the success of the program.

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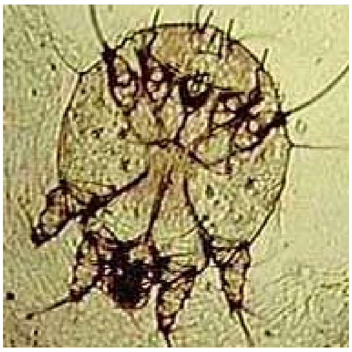

A scabies mite

A BIG day of chemistry

– David Salt

At the end of May research chemists from ANU ventured beyond their lab benches to share their expertise and enthusiasm with the general public. It was all part of a very 'BIG day of Chemistry' at Questacon in which kids and their parents were given the opportunity to make their own latex balls, build molecular models, play with glow sticks and hear from some of the country's top chemical brains talk about the importance of chemistry to our everyday life.

The researchers came from the Research School of Chemistry and the ARC Centre of Excellence for Free Radical Chemistry and Biotechnology (the Free Radical Centre). They initiated the day to showcase innovate research being undertaken at the Free Radical Centre and in the Research School of Chemistry.

"It was a fabulous experience," says Ms Felicity Jensz, Community Awareness Manager for the Free Radical Centre. "It's the first time so many real chemists have gathered at Questacon on one day to engage the general public. There were lectures, demonstrations, computer games and simulations. And the researchers were showing visitors the science behind such basic things as face cream, glow sticks and latex."

But it wasn't just about the science. Many of the researchers also wanted to break some of the stereotypes that have grown up around research chemistry.

"People coming along to the BIG day of chemistry have met one whole research group," says Dr Mary Gresser. "We hope they have seen that we're actually pretty normal people. You could run into us on the street and you wouldn't really know we're research chemists."

Two chemists from the Research School of Chemistry, John Antony and Isaac Arthur, demonstrate the chemistry of glow sticks at the recent Chemistry at Questacon

"We're trying to break the stereotypes that researchers are just lab bound people always hovering over bubbling solutions," comments Dr Zac Watts. "We showed visitors at Questacon that chemistry is fun, but also that research in chemistry is about working on things that are around us all. Chemistry is the stuff of life. Most people don't really appreciate that everything they use, everything they eat and drink, are made of chemicals."

"We've also tried to demonstrate how powerful the new chemical technologies can be," says Dr Hideki Onagi. "For example, nanotechnology is all about chemists building molecules and giving them functions. We can have these molecules self assemble to form big arrays or molecular chips or wires or devices. Through our computer simulations we've tried to show the general public the power of technology."

"And we have been raising the awareness of people on some of the chemicals that exist in products all around us," says Dr Amy Philbrook: "Polymers, for example, are the basis of all our plastics and resins that dominate our lives. We've been doing experiments throughout the BIG day of chemistry where visitors have made bouncy balls by mixing in vinegar to a liquid latex solution. This sets off a polymerisation process that leads to the formation of a bouncy white latex ball."

"In all these demonstrations, we've tried to show people that chemistry isn't scary, and that research chemists are normal people," says Dr Ryan Dawson.

And, based on the smiling faces of children walking away with glow sticks and bouncing latex balls, it looks as though the research chemists have succeeded.

More info: www.freeradical.org.au

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