THE UNIVERSITY OF BRISTOL MAGAZINE // WINTER 2012

nonesuch

HOW PURE MATHS KEEPS US SECURE

TAKING STOCK OF EGYPTIAN COFFINS

QUANTUM PHYSICS YOU CAN DANCE TO

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Medical sciences teaching on the move

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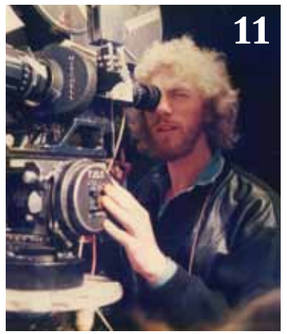

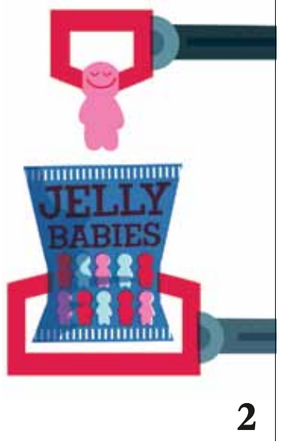

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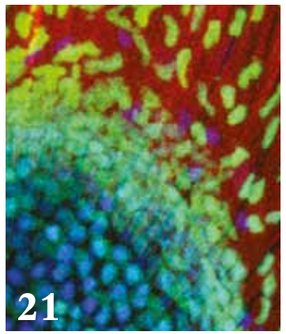

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Editors
Hilary Brown
Nick Riddle

Contact
nonesuch@bristol.ac.uk

Contributing Editor
Freya Sterling

Advisory Group
David Alder // Director of Communications and Marketing
Jill Cartwright // Head of Public Relations Office
Dr Lorna Colquhoun // Head of Research Development
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Tania Jane Rawlinson // Director of Campaigns and Alumni Relations
Professor Judith Squires // Dean of Social Sciences and Law

Design
pelotondesign.co.uk

Produced by
Public Relations Office
Senate House
Tyndall Avenue
Bristol BS8 1TH
T: +44 (0)117 928 8895

Cover illustration
Sarah J Coleman

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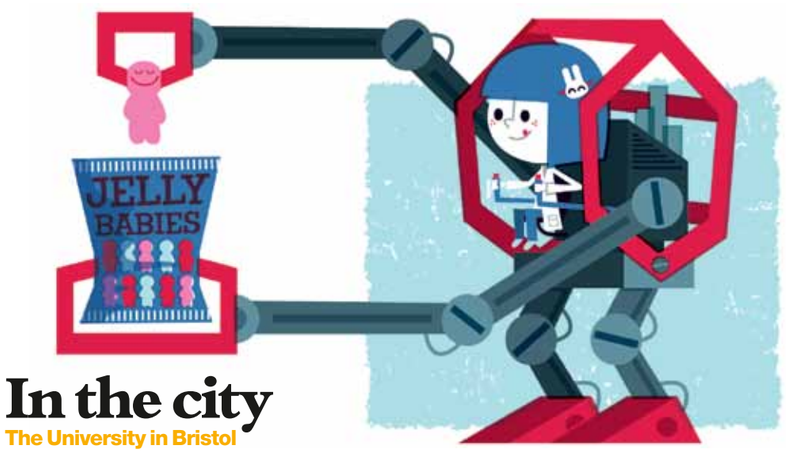
Regulars



In the city
The University in Bristol

Robogals is an international, student-run organisation that aims to encourage schoolgirls to pursue an interest in engineering, science and technology, and ultimately to increase female enrolment in such courses at university. The Bristol chapter made its debut at the University's Changing Perspectives event in 2011.

Under the scheme, trained student volunteers – female and male – visit local primary schools to run robotics workshops for girls, using LEGO's Mindstorms NXT package to explain the basics of engineering, robotics and programming. Volunteers also act as mentors for teams in school robotics competitions.

'Most recently we've been running weekly sessions with pupils at Cabot Primary School in St Paul's,' says Emma Crichton, an MEng student in Civil Engineering and President of Robogals Bristol. 'We've been giving interactive presentations on all kinds of topics, and running workshops involving LEGO robotics, house design, and house building with the highly scientific tools of spaghetti and jelly babies.'

Robogals will also be present at 'Discover Bristol', Cabot Circus (8-10 March).

robogals.org // emma@robogals.org.uk

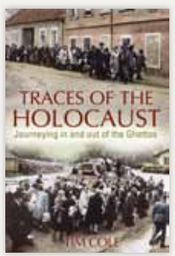
Rosebud
Everyday objects with a special meaning

Professor Jeremy O'Brien,
Centre for Quantum Photonics

Science has always been a hands-on matter for me. When I was a kid, my Dad's Erinmore Flake tobacco tins featured heavily in a lot of our experiments. I once spent a weekend scraping sulphur off hundreds of match-heads, then compressing it all into an empty bullet casing. Dad, being a bit of a pyromaniac, decided it was safer if he launched it. So he made a launchpad out of a tobacco tin lid and heated the bullet with a match. And it exploded, as you'd expect, and was gone, never to be seen again.

Robogals illustration © Peskimo

The plug
New books



Traces of the Holocaust: Journeying In and Out of the Ghettos
by Tim Cole (Continuum)

This study by Dr Tim Cole, Senior Lecturer in Social History, uses multiple perspectives and material traces to tell stories of journeys into and out of Hungarian ghettos. The dimensions of the Holocaust are revealed in these accounts of the perpetrators who oversaw ghettoisation and deportation, the bystanders who witnessed and aided these journeys, and the victims who undertook them. The stories also point to the visibility of these events within ordinary spaces in the city and the gendering of the Holocaust in Hungary.

Ovid in the Middle Ages
edited by James Clark, Frank Coulson and Kathryn McKinley (Cambridge University Press)

The work of the Roman poet Ovid has influenced writers from Dante and Shakespeare to James Joyce and Bob Dylan. This new collection of essays, co-edited by James Clark (BA 1992), Professor of History, examines the enthusiasm for Ovid in the Middle Ages. Topics include manuscript and textual transmission, translation, adaptation and imitation, as well as cultural contexts such as schools (monastic and secular), courts and literate households.

In pictures

Snapshots
Life and work at Bristol

Clockwise from left.

PAINT-MARKED NEST SCOUTS // Bees shed light on human decision-making. **bristol.ac.uk/news/2011/8105.html**

570-MILLION-YEAR-OLD FOSSIL // Evidence of single-cell ancestors. **bristol.ac.uk/news/2011/8126.html**

GOLD OF ANCIENT PANAMA // One of 250 objects featured in new book on pre-Columbian goldwork of Panama. **bristol.ac.uk/news/2011/8013.html**

CHILEAN PORTRAIT // Winning entry in SML Photographic Prize 2010-11. **bristol.ac.uk/sml/undergraduates/stuinfo/galleryya1011**

GOING GOING GONE // University's life-size gorilla. **bristol.ac.uk/news/2011/7948.html**

Honeybees © Thomas Schlegel // Gran Cocle, Seahorse Effigy Pendant Accession# 6645.208 © Gilcrease Museum, Tulsa OK. // SML competition winner © Alex Oppenheim

Feature

In the fast-evolving world of medical sciences, developing innovative teaching tools has never been more important. Thanks to schemes created by the Applied and Integrated Medical Sciences Centre for Excellence in Teaching and Learning, Bristol is leading the way.

Aiming for excellence

By **Chris Wraight**

Meeting Stan D Ardman for the first time is a slightly unsettling experience. He doesn't move much, though his eyes blink from time to time. He breathes fairly normally – something you can feel if you put your hand in front of his perpetually smiling mouth. He has a pulse, his pupils dilate, and he knows how to make a nice cup of tea.

Okay, so he doesn't know how to make tea, but everything else is true. Stan (pictured) is an astonishingly capable full-sized manikin designed to simulate a wide range of physiological functions. His responses are controlled by a powerful computer, which also monitors his heart rate, blood pressure, and other vital signs. All of these can be viewed on an *ER*-style console in real time, giving students a close approximation to a real-life situation. When his technician makes use of his in-built microphone, Stan can even 'speak'.

Animating Ardman

Stan spends his time in the School of Medical Sciences, where he's used to teach a wide range of students about physiological and pharmacological principles, using scenarios custom-written by teaching staff at Bristol. His body also responds to a range of drugs in just the same way a real patient would, giving medical students the opportunity to take the lead in diagnosing symptoms and providing treatment. Unlike real patients and student volunteers in practical classes, Stan doesn't object to catheters being inserted into his heart or his oxygen supply being cut off.

These capabilities make Stan invaluable for showing students what normal body function looks like, as well as simulating real-life diagnosis and treatment. 'By using Stan as your model subject, you can do all sorts of things that you can't do to a real person,' says Professor Judy Harris from the School of Physiology and Pharmacology. 'If medical students do something wrong when they "treat" Stan, the teacher can just turn the clock back by 15 minutes and explain why.'

Stan is just one of several projects funded by the Centre for Excellence in Teaching and Learning (CETL) for Applied and Integrated Medical Sciences (AIMS). The CETL grew out of the need to ensure that Bristol's world-class research reputation was matched by first-rate teaching and learning.

As Harris says, 'Bristol already had very high-quality teaching, but we had the potential to develop really innovative teaching. We also had talented people willing and able to commit to new projects, so we were invited to bid for funding. It was a huge amount of work!'

Feature

Left Derek Telling (left), Professor Judy Harris and Dr Gus Cameron

That work paid off in 2005, when the University's strength in teaching medical sciences was recognised with a grant of £5 million from the Higher Education Funding Council for England. The resultant AIMS CETL (initially co-directed by Harris and Dr Richard Greene until the latter's departure in 2008) has since funded a whole range of projects, from Stan to virtual microscopes, to roving labs on wheels, to full-scale anatomy suites.

Keeping it real

Despite the cleverness of Stan's virtual body, the need for medical students to gain experience of working on real human tissue remains. The Clinical Anatomy Suite (CAS), designed by Greene and based in the University's Centre for Clinical and Comparative Anatomy, provides first-class facilities for working on bodies generously donated for medical teaching and research.

Derek Telling chairs the group overseeing the development of the suite. 'We built it for undergraduates and postgraduates, based on courses we'd been running for some time,' he says. 'But then a change in the law allowed us to use whole-body human donors for surgical training, so consultants can now use our facilities to train young people in surgery – including completely new techniques. We were also one of the first to develop a system for making extensive use of fresh rather than embalmed material, giving greater flexibility and colour.'

The work of the CAS has since encompassed both professional development and research, and has drawn attention from across the world. The proximity of teaching hospitals and private-sector surgical institutions has resulted in a cluster of expertise around the CAS. 'Put that together with the Centre's anatomical expertise,' says Telling, 'and you have a leader in the field.'

Going virtual

Other CETL projects do away with physical equipment altogether. The Virtual Microscope allows medical, dental and veterinary science students to study slides of tissue sections on screen. Instead of relying on real slides – which can be hard to source at a consistent quality – the virtual equivalent provides extremely high-resolution images that can be zoomed into, panned across, and even annotated. All of this is controlled through a standard web browser, so that students can access their slides in the lab, in the library, or from the comfort of their rooms.

WE HAD THE POTENTIAL TO DEVELOP REALLY INNOVATIVE TEACHING

Using a virtual microscope has many advantages over the mechanical version. The same image can be used by an entire class, which ensures that each person is working from the same source and that assessments based on the images are consistent. Overlaid notes can point out areas of particular interest on the slide, and the software can generate revision quizzes using the image data, providing students with feedback on their level of understanding. As Harris says, 'Looking down a microscope can be quite a lonely occupation, but the virtual equivalent allows groups to gather round and discuss the image. The result is a more stimulating and useful experience for both students and teachers.'

Similar functionality is provided by the eBiolabs suite of laboratory tools. This software originated in the School of Biochemistry to improve the quality of students' lab work. Dr Gus Cameron, the project's director, explains: 'We weren't happy with the way that the students were getting to grips with practical laboratory teaching. As research scientists, the hands-on stuff is what we're really passionate about.'

eBiolabs simulates a whole range of laboratory tasks, letting users get the hang of expensive and complicated equipment without the risk of causing damage or wasting valuable preparation time. Through high-quality animations, step-by-step tutorials and online assessment exercises, students learn how to get the best out of the equipment available to them. As well as proving more convenient than the old paper-based lab manuals, eBiolabs has changed attitudes to practical work. 'Students now associate words like "stimulating" and "interesting" with practicals, rather than "boring" and "repetitive",' says Cameron. 'They now value the practicals far, far more than they ever did before.'

WE HAVE REVOLUTIONISED HOW STUDENTS RELATE TO PRACTICALS

Since work began on the eBiolabs tools four years ago, the capability of the suite has expanded rapidly. The software now includes revision exercises for students, tracking of assessments, space to upload data, and tools for manipulating statistics. New functions are being added all the time, and the tools have been adapted for use in other related subjects, such as physiology, pharmacology and pre-clinical medicine. In the four years since its creation, eBiolabs has evolved from an online replacement for lab manuals to a fully integrated tool for teaching, assessment and tracking achievement.

Its popularity with students is such that one claimed to spend more time using it than anything else online except Facebook. Staff have also taken advantage of the opportunities on offer. 'We have revolutionised how students relate to practicals, and that has changed how staff relate to them as well,' says Cameron. 'Staff are having a much higher level conversation with students; instead of "No, you press this button, or that button", it's "Look at this, now let's interpret the data".'

Out and about

The final element in the AIMS CETL's range of schemes is slightly different, in that it's not aimed primarily at either undergraduates or medical professionals. The Mobile Teaching Unit (MTU) is an HGV-sized lorry that expands when parked to create a teaching space capable of accommodating 20 people. The MTU is kitted out with computers and monitoring equipment, enabling participants to record their blood pressure, take an electrocardiogram reading, or measure their lung capacity. Practical demonstrations can be performed in the MTU's dedicated laboratory facilities, supplemented by the audio-visual displays.

The teaching staff on board the MTU have to be very flexible, coping with young schoolchildren, sixth-form students and adult members of the public. The content of the training programmes has been designed to complement the school human biology curriculum, allowing pupils to take advantage of equipment normally only available to undergraduates.

The MTU is a unique tool for the promotion of public understanding of science, but it's also a great advertisement for the University, which is especially important given the current emphasis on widening participation. 'The MTU's helping tremendously in terms of promoting higher education and encouraging people who might not otherwise have thought about going on to do a degree,' says Harris. 'If they didn't know much about university or they found it a bit daunting, then the MTU and the staff who teach in it can help change those perceptions.'

Together, the projects funded by the AIMS CETL grant have transformed the tools available for teaching in the medical sciences. All five schemes continue to develop, and there's plenty of potential to make them even more useful in the future. As Harris says, 'Medical science is a practical subject, and it's really important for students to get in there and do hands-on work. The facilities that we now have for students to do that in Bristol are absolutely second to none.' ●

bristol.ac.uk/cetl/aims

Top Virtual and light microscopy in action
Bottom Neuroanatomy teaching in the Clinical Anatomy Suite

Portrait © Dan Rowley // Teaching photos © Dave Pratt // Stan © MEDI

Regulars

From Bristol to London

Freya Sterling interviews **Maxine Room** (BEd 1979, MEd 1993), Principal and Chief Executive of Lewisham College, London

My mother encouraged a positive approach to learning. She believed that we could overcome any barriers. She made me believe that anybody could achieve what they wanted to in life, regardless of race, gender or disability.

Originally, I trained as a teacher and loved it. I taught vocational courses, GCSEs and A-levels in a range of subjects such as social sciences, childcare, health and social care. My desire for inclusivity was sparked while I served on the equal opportunities group at Bridgwater College and it steered me towards doing a Masters degree.

I wanted to write something academic in the area of equalities. After I had been teaching for a few years I had the urge to write and decided on a Masters degree at Bristol focused on multicultural education and equalities.

My MEd helped me over the teaching threshold and into management. I have always reviewed my career without thinking about my race or ethnicity. However, when I was appointed at Swansea College in 2003, I was the first black principal of a further education (FE) college in Wales and the second in the UK. The fact that there are remarkably few black and minority ethnic (BME) senior managers in the FE sector indicates that there are underlying factors still to be addressed.

For as long as I've been a principal, I've been a mentor. I believe that, as a sector, we have the responsibility to bring on the next generation of leaders and managers. Initially, I began mentoring as part of the Network for Black Professionals and the Black Leadership Initiative working with BME managers and senior managers in FE colleges. My role was to support them in progressing upwards into their next role.

As a trustee of the Helena Kennedy Foundation, we also strive to overcome social injustice by providing financial bursaries, mentoring and support to disadvantaged students from further and adult education sectors. We ensure that all those who want access to education can get it, for the purpose of sustainable employment and not just education for education's sake. This is something which is also inextricably linked with our vision at Lewisham College.

Lewisham College is a member of the 157 Group of high-performing colleges, and has a population of 16,000 students and growing. This is my third principal/CEO role and despite the ever-changing financial climate, my focus is on growing our vision of creating successful futures and working in partnership with other colleges.

By working together in FE education, we'll be able to become more effective and efficient. We will be able to offer better choices in the curriculum, and ensure links with employers and solid progression routes for our students. The modules I did at Bristol helped to frame my thinking to this day, in terms of self-development and equality, and laid the foundation that has helped me to become the manager I am today.

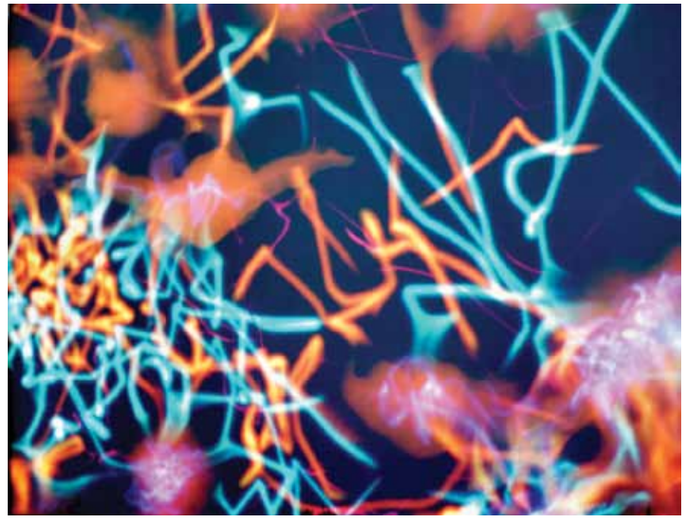
ANYBODY CAN ACHIEVE WHAT THEY WANT IN LIFE REGARDLESS OF RACE, GENDER OR DISABILITY

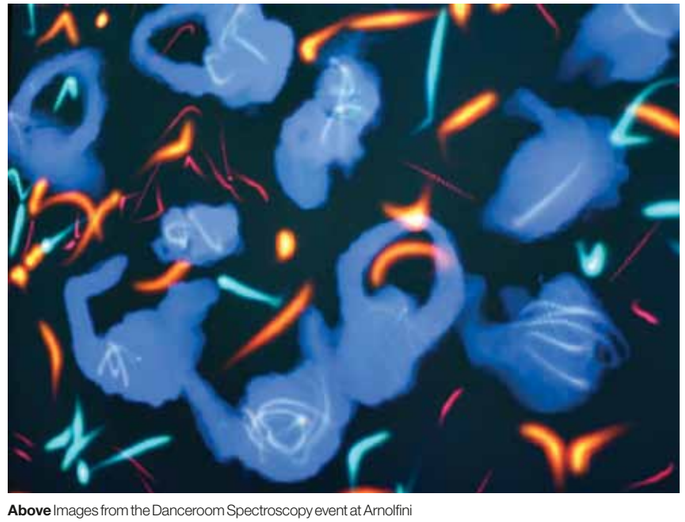
Portrait © Stephen Shepherd

Feature

The light fantastic

Nobody knows what the quantum world looks like. But scientists and artists can't help wanting to picture it. **Dr David Glowacki** has pioneered a more imaginative approach than most, with help from a programmer, a choreographer, a musician, and an assortment of other artists and academics.





Above Images from the Danceroom Spectroscopy event at Arnolfini

By **Nick Riddle**

In a large, darkened room, people are moving their arms around slowly above their heads and watching their own silhouettes interact with brightly-hued, protean shapes on a giant screen. It looks a little like a 21st-century séance ... but it isn't. It's a mixture of quantum physics, classical physics, art, computer code and human beings. And it's called Danceroom Spectroscopy.

The 'Danceroom' part is probably self-explanatory. 'Spectroscopy' might be another matter.

'Spectroscopy is the use of light to obtain information about matter,' says Dr David Glowacki, a chemical physicist (among other things, but we'll come to that), and the brains behind this striking science/art hybrid. If a spectrometer sounds like a niche item of equipment, think again: most of us have two of them. 'Our eyes are actually little spectrometers,' says Glowacki. 'But eyes have limitations: they can only resolve change that happens on relatively slow timescales, and there's a lot they can't see.' Different kinds of light, for example, or the microscopic and nanoscale world.

Scientists have a similar problem, he explains: 'We're always imagining what the microscopic world looks like. We're a little obsessed with fictitious representations, in fact – balls and sticks, blobs, terraces, cavities, ribbons, sheets. The truth is, we don't know exactly how it looks, but we make pictures anyway.'

Putting on a show

Danceroom Spectroscopy is a new attempt to visualise the atomic world, but with a difference: it puts us into the picture. A suspended 3D imaging camera captures the movements of people below; that motion is fed into a laptop and translated (via software) into energy fields, which in turn warp the particle dynamics of a simulated nano-world. It's similar to the effect of a pebble dropped into a pool, only the pebbles get to watch themselves, and the complex ripples they create, on a projection screen.

It's an experience for the ears as well as the eyes: the human interactions with these simulated particle fields are mapped onto musical scales to generate a soundtrack of tones, melodies and rhythms. And that, it turns out, was the starting point for Glowacki.

'It came out of a conversation in the pub with a musician friend of mine, Lee Malcolm,' he explains. 'I was getting frustrated with the music-generated-by-motion idea, which has

Feature

been done to death, and I started thinking about different approaches to it, inspired by my day job as a scientist.' Only then did he begin to realise the potential his ideas had for opening up the world of quantum mechanics, using the same algorithms he employed in his research.

With a grant from the Engineering and Physical Sciences Research Council and support from Professor Mike Ashfold in the School of Chemistry, Glowacki sought out collaborators: Phil Tew, a programmer from the Pervasive Media Studio at Bristol's Watershed; Laura Kreifman, a dancer and choreographer from the Guerrilla Dance Project; artist and designer Becca Rose; and Professor Joseph Hyde from the Music Department at Bath Spa University. After series of tryouts in small venues, Danceroom Spectroscopy had its first proper outing at Arnolfini on Bristol's Harbourside in the summer of 2011.

Above Dr David Glowacki

Particle man

Glowacki's job title – Research Assistant in the School of Chemistry – doesn't come near to doing justice to the scope of his interests. Born in the States, he studied philosophy and comparative literature alongside science subjects as an undergraduate. 'I've always been fascinated by the ancient philosophers who did everything,' he says: 'some science, some philosophy, some music, some art...'

He came to the UK as a Fulbright finalist to do a Masters in cultural theory and religion ('I studied how George W Bush turned Christian ideology into military strategy during the War on Terror'), before concentrating on science. Since then, he has published papers on topics in classical and quantum dynamics, biochemistry, computer programming, atmospheric chemistry, scientific instrument development and optics.

IN SCIENCE IT TAKES A LONG TIME TO GET STUCK IN – YOU CAN'T BE SUPERFICIAL

How does he manage to cover so much ground? 'I don't sleep that much,' he admits. 'The most difficult part is pulling myself out of concentrating on one thing and moving over to something different. In science it takes a long time to get properly stuck in – you can't be superficial. But like most things, the more you do it, the better you get at it.'

For the average person, giving equal attention to such a panoramic spread of interests would be as challenging as trying to visualise the quantum world. To Glowacki, it's second nature.

'At heart I'm a scientist, in the sense that I'm systematic in my approach to knowledge,' he says. 'But I think I'll always maintain a range of specialisations; I don't have the makeup for anything else.'

Going towards the light

Now that science is addressing topics of ever greater complexity – environmental sustainability, next-generation fuels, reforming the economic system – the benefits of having omnivores like Glowacki on hand are obvious. One large-scale project he has just begun to think about concerns the physics of photosynthesis.

'Plants turn sunlight into fuel,' he explains, 'and there's evidence to suggest they may be exploiting some wave features in quantum mechanics to get the energy from the surface of the leaf into the centre of the cell where the chemical reactions happen.'

Getting to the bottom of that process would involve collaborations with biologists, physicists, mathematicians, chemists, engineers ... in other words, it's right up his street. ●

davidglowacki.wordpress.com/arts

Danceroom lessons

Glowacki's work shows how an imaginative approach to science and art can appeal to both the scientist and the lay person.

Watching people interact with the virtual particles is itself a lesson in human behaviour: Glowacki has seen a kind of accelerated human evolution, as individuals move from solitary, tentative interaction to choreographing their movements with strangers in order to create more dynamic patterns. 'We had a group of schoolkids trying it, and everyone wanted to keep their particles to themselves,' he says. 'The sound stopped, and nothing much happened on the screen until they started sharing and collaborating.'

Wider audiences will get the chance to try collaborating as Glowacki is taking Danceroom Spectroscopy to the 2012 SXSW festival in Texas, along with plans to put on a wave-themed installation in a 360-degree surround projection dome, at the 2012 Cultural Olympiad in Weymouth.

Portrait © Jason Ingram // Danceroom spectroscopy images © Sam Saunders

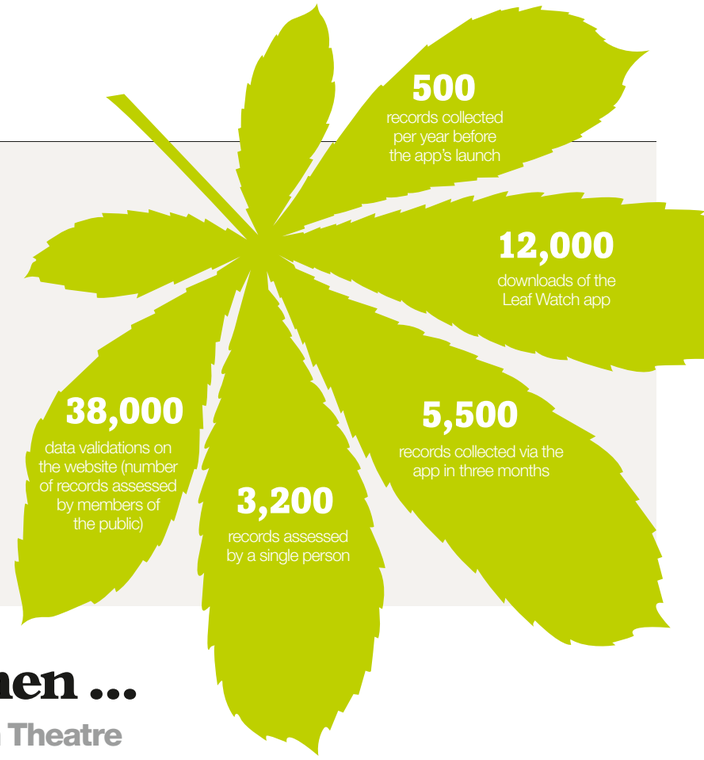
Regulars

Numbers
On the trail of the killer moths

A project by the Universities of Bristol and Hull has been tracking the incursions made by an alien moth, the horse chestnut leaf miner, a scourge of the UK's conker trees since 2002. In 2011 the project launched a smartphone app, funded by JISC and developed by Bristol's Institute of Learning and Research Technology.

The **Leaf Watch** app enables users to send their images of leaves damaged by the moths, along with metadata that is then assessed by other users. It was featured in the national media and received a boost after being tweeted about by Stephen Fry.

leafwatch.naturelocator.org



What happened when ...
... 'Sledgehammer' hit the Wickham Theatre

'Sledgehammer' crew © Dave Alex Riddett

It's one of the most famous pop videos of all time, with a record nine MTV Video Music Awards, and it helped propel a young company called Aardman Animations into the big time. But in the spring of 1986, the creation of the promo video for Peter Gabriel's single, 'Sledgehammer', was bringing chaos to the Drama Department's Glynne Wickham Theatre.

'Peter wanted to use a director called Stephen R Johnson, who'd just done the video for Talking Heads' "Road to Nowhere",' says Dave Alex Riddett (Cert 1978), who was Principal Cameraman on the production. 'But he wanted it done in England with a UK crew.' So Aardman got the call.

Having shot the early sequences in Aardman's Clifton studio, the production needed a larger space for the final animated dance sequence. Aardman had used the Wickham Theatre for one of its first advertising commissions (for Enterprise Computers in 1984), and returned there with Gabriel and the crew (augmented by Drama students and staff) for two days of shooting.

'We had six large backdrops that we also animated,' says Riddett, 'and every two frames we had to change the scenery. You hardly notice in the final video, but things in the background are moving all over the place.'

The extras included some local girls recruited from St Paul's, whose excitement at being in a music video faded somewhat after the first seven hours. 'They had to dance frame by frame, and hold position while we moved props around,' says Riddett. 'It was all done on the wing: Steve kept having these crazy ideas and changing his mind about where he wanted to cameras to move. Eventually the girls said, "We don't want to do this anymore, we're exhausted!" So we animated some chairs coming in. That's why they're doing the last bit sitting down.'

EVERY TWO FRAMES WE HAD TO CHANGE THE SCENERY

'The shoot ended around 2 am, and we kept animating ourselves having the wrap party,' he adds. 'I've no idea where that footage is now.'

Above Peter Gabriel and the 'Sledgehammer' crew, including Dave Alex Riddett (Director of Photography on Aardman films including *Chicken Run* and the forthcoming *Pirates!*); Nick Park (Hon DLitt 1997), David Sproxton (Hon LLD 2010) and Peter Lord (Hon LLD 2010) (who turned Aardman – and Wallace and Gromit – into household names); and the Quay Brothers (makers of highly acclaimed films such as *Street of Crocodiles*).

Some of the hardest mathematical problems known to man are helping to keep our modern transactions secure. Professor Nigel Smart and Dr Elisabeth Oswald in the Department of Computer Science shine a light on the mysterious world of pure mathematics, and the cryptography that it makes possible.

Hard numbers

Cover feature

By **Nick Riddle**

'I am interested in mathematics only as a creative art,' said GH Hardy in his influential 1940 book, *A Mathematician's Apology*. Hardy was a champion of pure mathematics – and especially of number theory, his own specialist field. He argued passionately that mathematics is not only beautiful art, but is at its best when it has no application. And he foresaw a future for number theory unsullied by any practical use.

Some 70 years later, many of the systems we take for granted – the internet, the mobile phone networks, the banking system – rely on the arcane workings of pure mathematics for their very existence. Why? Because nobody trusts anybody else.

'If you want to do anything online – shopping, banking, or just emailing – you have to get reassurance that you're talking to Amazon, or your bank, or whoever,' says Professor Nigel Smart, Director of the Cryptography Group. 'And they often need the same reassurance that you're who you say you are.'

The same is true of the high street, says Senior Lecturer Dr Elisabeth Oswald: 'Shops don't trust that your credit card is valid – and you don't trust the shop not to "skim" your card.'

In both cases, trust is established by using cryptography: our computers make contact with the online world via encrypted 'handshakes'; and the chip-and-pin systems on our cards require us to enter our 'key' before we get the goods. The idea is now so ubiquitous that looking back a mere 35 years feels like visiting the steam age.

The key to cryptography

'Prior to 1976 if two people wanted to communicate securely without meeting, someone would have to transport a key physically from point A to point B,' says Smart. 'For the hotline between Moscow and Washington, they would send numerical keys – on discs, or tape or whatever – back and forth every month by plane.'

In the mid-1970s, a handful of people at Stanford University and MIT looked again at number theory and developed a new kind of cryptography. 'They worked out that you could securely agree a key without ever having to meet,' says Oswald. 'You can transmit public numbers and can come up with a secret number – and that only works because of certain properties of numbers that you find when you study number theory.'

So how does number theory help to keep a secret? Smart offers a simple example: 'It's easy to multiply two numbers together, but harder to split it into its prime factors. If I give you 7 and 11, it's easy for you to multiply them together to get 77. But if I give you 77, you have to know about the number 77 to be able to split it into 7 and 11. Now, instead of 7 and 11, think of a *very* big prime number and another *very* big prime number, then multiply them together. That even bigger number is much harder to split up.'

MANY SYSTEMS WE TAKE FOR GRANTED RELY ON PURE MATHEMATICS

A secret history

c100 BC
Caesar cipher

1467
Polyalphabetic substitution cipher

1553
Vigenère cipher

1917
Vernam cipher

1923
Enigma machine

1973-76
Discovery of public key encryption

1976
Data Encryption Standard

2001
Advanced Encryption Standard

Cryptic Bristol

Smart was appointed to the Computer Sciences Department to set up the Cryptography Group, now one of the largest such groups in the world. 'From the outset we planned to cover the whole spectrum, from poking at circuit boards through to doing highly esoteric mathematics,' says Smart. With the formation of the European Network of Excellence for Cryptology (ECRYPT) in 2004, it was a sign of the Cryptography Group's growing stature that its members took the lead in organizing research meetings, insisting, says Oswald, 'that people should come together in order to achieve something, rather than just to hear someone give a talk then go away and have coffee.' When the second phase of ECRYPT began in 2008, the Bristol group played a major role in setting its agenda.

The magic of maths

The world of pure maths leads you down some odd byways that give rocket science a run for its money. One avenue in particular has long held an appeal for cryptographers: fully homomorphic encryption. If the cryptography behind the internet presupposes a lack of trust, then this most sought-after form takes suspicion to new levels.

But what *is* fully homomorphic encryption? 'It really is a bit like magic,' says Oswald.

'Fully homomorphic encryption allows you to compute on encrypted data,' explains Smart. 'You can send your data to someone you don't trust, and you can then ask them to compute on this data for you and send you back the results, which will still be encrypted, so they can't read the results either.'

Partially homomorphic encryption has been in use for a while, for example in voting systems; this, however, only allows addition. But a paper written by a US researcher, Craig Gentry, in 2009 offered theoretical proof that fully homomorphic encryption was also possible. Using this system, says Smart, 'you could add *and* multiply – which means that you could compute any function on any encrypted data'.

Even after Gentry's paper, this was considered Alice in Wonderland territory – until another paper, co-written by Smart (with Dr Frederik Vercauteren from the Katholieke University Leuven in Belgium), demonstrated that it was much closer to the realms of the possible than previously thought.

'Gentry's thesis is 200 pages long, with dense, impenetrable maths that maybe 10 people on the planet could understand,' says Smart. 'But we came up with a simplification that meant we could write out a fully homomorphic encryption scheme in just four lines on the blackboard [reproduced in the lead image]. Now it's relatively easy for a PhD student to understand, and that means it's easier to implement.'

The paper attracted the attention of the US Department of Defense. Its research arm, DARPA ('The people who invented the internet and the GPS system,' says Smart), announced a $20-million research programme on fully homomorphic encryption, and on the short reading list for anyone wishing to be involved was Smart and Vercauteren's paper. As a result, members of the Cryptography Group are now part of the international consortium working on the project.

Leaps of faith

If doing the mathematics itself sounds like a linear process, that might be because of how we're used to learning maths at school: as a sequence of logical steps. In fact, says Smart, 'a lot of it is insight and invention; it's closer to art'.

Take that simplification of homomorphic encryption from 200 pages to four lines. 'We started working on it, and noticed that the numbers coming out were really, really weird,' says Smart. 'Your immediate reaction is "This should never happen", but you take a leap of faith, because the numbers are talking to you, saying "Find out the property", and you say: "I wonder what happens if I do this – or this?". That's art – the inventive step. Then you have to prove that that property always holds.'

But that inventiveness needs foundations: the 'bricks and mortar' of mathematical principles. And there's no getting around that, says Smart: 'You need to cover loads and loads of boring stuff before you're able to do cool stuff. It's like music: you can't write a symphony before you've done your scales and arpeggios.'

The harder they come

For most areas of science, difficult maths would present an obstacle: 'For us, the hard mathematical problems are what make cryptography work,' says Smart. 'If you can break our systems, you can do something that mathematicians think is impossible.'

And in case you're wondering *how* hard these 'hard mathematical problems' are, Smart has an illustration. 'There's an algorithm called Advanced Encryption Standard which is commonly used to encrypt data, and it uses a key which is 256 bits long, which is equivalent to a decimal number with 77 digits. If you did a brute force search on that key, which is the most common attack, and you expended a millionth of a joule of energy in checking each bit – and that's astronomically low – you would use up all the energy in the universe.'

'So theoretically, it's possible,' says Oswald. 'You could find the answer. But you would destroy the universe in the process.' ●

cs.bris.ac.uk

Plugging the leaks

To get the security of a system right, mathematics will only get you so far. Oswald's special expertise lies in an area known as side channel attacks – a category of attack that involves finding 'leakages' from what we all probably think of as secure transactions.

'A good example is your mobile phone,' she says. 'Clever cryptography runs on it via a computer program that consumes power and emits electromagnetic signals.' If you know how to 'read' the power consumption and signals (and there are plenty who do), you can decode certain pieces of information – in the worst case, pretty much everything.

These compromising emanations were well known in the military, and led to the construction in the 1970s of shielded rooms where communications could be carried out without leaking electro-magnetic radiation. But the rest of us were wide open until the late 1990s. 'Back then, we could analyse any bank card or smart card and we could read the keys,' says Oswald. That this is no longer the case is partly down to Oswald herself, who co-wrote the first comprehensive account of power analysis attacks and the range of countermeasures.

'It's a cat-and-mouse game,' she says; 'I have to find a defence against a particular threat – something that can be implemented quickly. Then someone will try to get round it.'

Feature

Case histories

The UK's provincial museums hold a wealth of artefacts from the death rites of the Ancient Egyptians. Exactly how many? Nobody knows. Dr Aidan Dodson – Egyptologist, civil servant and lecturer – is on a mission to find out.

By **Nick Riddle**

Plenty of eight-year-old boys have a morbid interest in skeletons and the grisly paraphernalia of death rituals. For Dr Aidan Dodson, Senior Research Fellow in the Department of Archaeology and Anthropology, that curiosity took hold, to the point where he is now a recognised expert in the archaeology of death – especially in Ancient Egypt.

He was, therefore, a natural choice when the National Museums of Scotland were seeking help with cataloguing all the Egyptian coffins held in their collections. 'Once we'd worked out a modus operandi for that, it made sense to extend the project,' he says. 'Britain's provincial museums have a lot of very interesting material that's never been properly documented, particularly where coffins are concerned.'

Rabbit holes

The presence of so many Egyptian coffins in museums all over the country has a lot to do with Britain's imperial past, when the well-to-do would embark on Grand Tours and return with trinkets large and small. 'Most were acquired in the 19th or early 20th centuries,' says Dodson. 'It sometimes takes a bit of sleuthing to work out how they came to be where they are.'

He gives the example of a pair of coffins now in Plymouth's City Museum, which were originally in Bristol: 'They seem to have been taken home by the Bristol curator in the mid-19th century because there wasn't enough room in the museum. After he died, his family thought they belonged to him, and tried to loan them to Bristol.' The Bristol Museum, who didn't realise that they already owned them, still hadn't the space, hence their arrival in Plymouth.

'There's a much bigger social history aspect to all this,' says Dodson. 'It's all tied up with the big old houses of Bristol and elsewhere. My main focus is still the coffins, but they take me down some interesting rabbit holes. There are all sorts of stories that one can dig up – literally, in some cases – to go with them.'

Fit for a king

Dodson's Grand Tour of British museums is also unearthing some unexpected finds. In 2011, he arrived at Torquay Museum to find a particularly striking coffin.

'I realised immediately that it was something special,' he says. 'It's cut from a single log of cedar wood and is exquisitely carved, inlaid and painted.' Since its donation in 1956 (by the daughter of sewing machine heir Paris Singer), the museum had suspected that the coffin had not originally been made for its present mummified occupant, a young boy. Dodson established that the coffin was indeed much older than the mummy – by nearly 1,000 years, dating from the 18th Dynasty, between 1525 and 1470 BC.

What's more, says Dodson, its sheer quality suggests that it may have been made for royalty, or at least for the son of a very senior official. His discovery made headlines in the British press, and the possibly-royal coffin and its mummy – named 'Psamtek' by its current custodians – is now the centrepiece of the Torquay Museum's Egyptian gallery.

Left Dr Aidan Dodson **Right** A reconstruction of 'Psamtek' at Torquay Museum

THERE ARE ALL SORTS OF STORIES THAT ONE CAN DIG UP

Eastward glances

Ancient Egypt has been part of the Western consciousness since at least the early 19th century, when the deciphering of the Rosetta Stone opened up Ancient Egyptian texts for the first time. The Victorian craze for things Egyptian influenced the architectural styles of the day, resulting in scores of buildings bearing the signature of an ancient world. One doesn't have to leave Bristol to see one, says Dodson: 'Brunel's original design for the Clifton Suspension

Left Detail of the coffin of the boy known as 'Psamtek' at Torquay Museum

Feature

Bridge had sphinxes, winged sun discs, and all sorts of ornamentation on the towers. That got scaled down when they ran out of money, but the shapes of the towers and their cornices come directly from the style of an Egyptian temple.'

Beyond the surface glamour of gold coffins and exotic monarchy lies a complex civilisation that lasted over three millennia. No wonder that Dodson has seen people come to it with a casual interest and begin to take it far more seriously. 'There are people who have been on tours I've led in Egypt, and have then signed up for evening classes and joined professional societies,' he says. 'Someone who did an evening class with me 15 years ago is now just finishing his PhD in Egyptology.'

Dodson has also been reflecting on his own progress, having recently been elected Chairman of the Trustees of the Egypt Exploration Society, the main British academic body for archaeological fieldwork in Egypt. 'I joined it when I was a schoolboy, so it's a strange sensation to recall looking at the extremely important names on the committee back then, and 35 years later there's me on the list.'

At the other end of the spectrum, Dodson sometimes gives talks in schools

BEYOND THE SURFACE GLAMOUR LIES A COMPLEX CIVILISATION

('I normally explain how the Egyptians took the brain out through the nose – that's always a popular one'), and media work that began with an appearance on Channel 4's *The Big Breakfast*. 'I had to demonstrate how to do mummification using a leg of lamb,' he recalls; 'I only had about three minutes to do the whole thing, but I'm told I did reasonably well.'

A servant of two masters

It's fitting that an ancient civilisation with such a highly developed bureaucracy has Dodson as one of its scholars: besides having held a part-time post at Bristol for the past 15 years, he has also spent a parallel quarter-century in the Civil Service.

It's a situation that suits him well: 'If I get fed up with one, I can switch to the other; and doing some research after work is actually a relaxation.' He also ascribes his high productivity – 15 books and some 200 papers and articles over two decades – to being a part-time academic.

'I've met quite a few people who burned themselves out,' he says. 'One of them chucked in her PhD about a week before submission, because it had all got too much and she'd lost her love of the subject. She went off to be a tax inspector.'

Dodson tactfully provides his students with a reality check: 'I tell them that the chances of getting a job in Egyptology are extremely small,' he says. 'But a lot of us do it on a part-time basis, and we're still able to leave our mark.' That's a message for students in any subject, he thinks: 'You've got all this knowledge of something, and you're really enthusiastic; just because you can't become a full-time professional academic, that doesn't mean you can't carry on making a contribution.'

bristol.ac.uk/archanth/staff/dodson

Egyptology at Bristol

'Bristol was one of the first institutions in the country to teach Egyptology, or at least Egyptian language, back in the 1890s, when it was still University College,' says Dodson. 'That was all down to one person, Ernest Sibree, who came here as the university librarian.'

'He was a great linguist – he wrote, spoke or knew a little of at least 15 languages, including a lot of eastern ones. There was a short-lived Department of Oriental Languages at University College, where they taught Sanskrit, Ancient Egyptian, Assyrian, Syriac – a whole raft of things. After Sibree's death in the 1920s, Egyptology at Bristol went quiet until the arrival of Mark Horton, who had worked in Egypt and began to teach a little on the subject. Students were enthusiastic for more, so when he discovered that my 'day-job' was about to bring me to Bristol, he jumped at the chance of getting a "proper" Egyptologist in to teach.'

Case in point

Translations from the inner coffin of Tairy, part of the Plymouth Museum's collections

Owner Tairy

Title Lady of the House

Father Butcher of Pharoah, Ashery

Mother Lady of the House, Denitenbastet

Portrait © Jason Ingram / 'Psamtek' © Torquay Museum / Tairy © Plymouth City Council (Museums and Archives)

Feature

Growing pains

Two recent studies by researchers in the Centre for Family Policy and Child Welfare are the first to examine the incidence and impact of teenage partner violence in Britain. NSPCC senior research fellow, Christine Barter, led the landmark reports, which have set alarm bells ringing among policymakers and practitioners.

By **Hilary Brown**

'I've never shouted rape or anything but it's not like I've given consent. In certain situations it has been pushed on me and it was really horrible. It was aggressive.'

Emma is relating her experiences of being forced by a boyfriend to have sex 'quite a few times' when she was 13. She is one of more than half the girls interviewed for a 2011 study of violence in the intimate relationships of disadvantaged teenagers to have reported sexual, physical or emotional partner abuse before the age of 18.

The research follows a pioneering study in 2009 on violence in relationships among teenagers in mainstream education. While the 2011 research suggests that children who have been excluded from school are more likely to experience partner violence than their counterparts in education, a third of girls in the earlier study suffered unwanted sexual acts while a quarter had been slapped, punched or beaten by their boyfriends.

Wake-up call

The studies' lead author, Christine Barter (pictured), isn't easily shocked. During her 20-year research career she has explored such issues as institutional child abuse, young people's experiences of racism, and peer violence in residential children's homes. The latter was the catalyst for the schools study when participants strayed from the original study remit to talk about violence by boyfriends – a previously under-researched topic in the UK.

But she was appalled by the prevalence of the violence in both studies and by the level of acceptance of abuse, particularly in the 2011 research. 'Violence appeared to be an everyday occurrence, and many girls saw it as normal – albeit unwanted – behaviour,' she says.

VIOLENCE APPEARED TO BE AN EVERYDAY OCCURRENCE

Other findings took her and her co-researchers by surprise. 'In both studies we found that partner violence was as common among 13-year-olds as among older participants,' Barter explains. 'Some girls even talked about being abused by their boyfriends at age 11 and 12.'

Controlling behaviour among all participants was more widespread than the researchers had expected, with young people using mobile phones and other new technologies to

Feature

keep tabs on their partners. 'Girls in particular felt under pressure to text their boyfriends to tell them what they were doing, or to take photos of themselves to prove their whereabouts,' says Barter. They struggled to distinguish between concern and control, and put up with unwanted demands because they felt scared, or feared they would lose their boyfriend, while boys were more likely to challenge their partner's behaviour.

Out in the open

The schools study attracted the attention of government, and formed part of an independent report into the sexualisation of young people. In the wake of the review, the Home Office launched a £2-million advertising campaign to raise awareness of violence in teenage relationships.

Barter's team was heavily involved in the campaign, advising on the storyboards for online films to accompany TV and radio adverts, and on content for posters (above right). The campaign website, 'This is Abuse', has been particularly well received by young people, and includes online polls, FAQs, videos showing violent scenarios from both boys' and girls' perspectives, and information about where to get help.

The campaign has been renewed in light of the 2011 study, a fact that Barter sees as endorsement of robust research that incorporates relevant statistical information as well as – crucially – the views of the participants themselves. 'It's not often that you see such direct effects of your research on policy, and one of the things that gave this work such impact was giving young people a voice,' she says.

Barter's relationship with the NSPCC is central to this work. Having a continued link with a charity dedicated to child welfare, she says, keeps her grounded: 'It's all about listening to what young people have to say and transferring those messages into policy and practice.'

The research has many implications for child welfare intervention; participants rarely reported their experiences to professionals, for example, so there is a need for practitioners to include an assessment of partner violence in work with young people. It also indicates that for some teenagers becoming pregnant is not a personal choice or an irresponsible 'accident' but something over which they have little control. In the future Barter hopes to explore more fully the role that sexual and physical violence or coercion plays in teenage pregnancy. ●

thisisabuse.direct.gov.uk

Above This is Abuse campaign posters

2009 study
Partner exploitation and violence in teenage intimate relationships

by Christine Barter, Melanie McCarry (PhD 1981), David Berridge (PhD 1981) and Kathy Evans

Methodology Survey of 1,353 young people between 13 and 17 from eight schools in England, Scotland and Wales; 91 in-depth interviews with 62 girls and 29 boys. 'We asked whole classes to take part in the survey, and interviewed those who were most engaged with it, as well as some of their peers. Many female interviewees reported feeling uncomfortable with controlling aspects of their partner's behaviour. For those with no issues, the main protective factor was having a focus other than boyfriends.'

Main findings

- a quarter of girls and 18% of boys reported physical partner violence
- nearly three-quarters of girls and half of boys reported emotional partner violence
- one in three girls and 16% of boys reported sexual partner violence
- most girls but very few boys reported that the violence had a negative impact on their welfare

Funders NSPCC and the Big Lottery Fund

Summary www.nspcc.org.uk/inform

2011 study
Standing on my own two feet

by Marsha Wood, Christine Barter and David Berridge (PhD 1981)

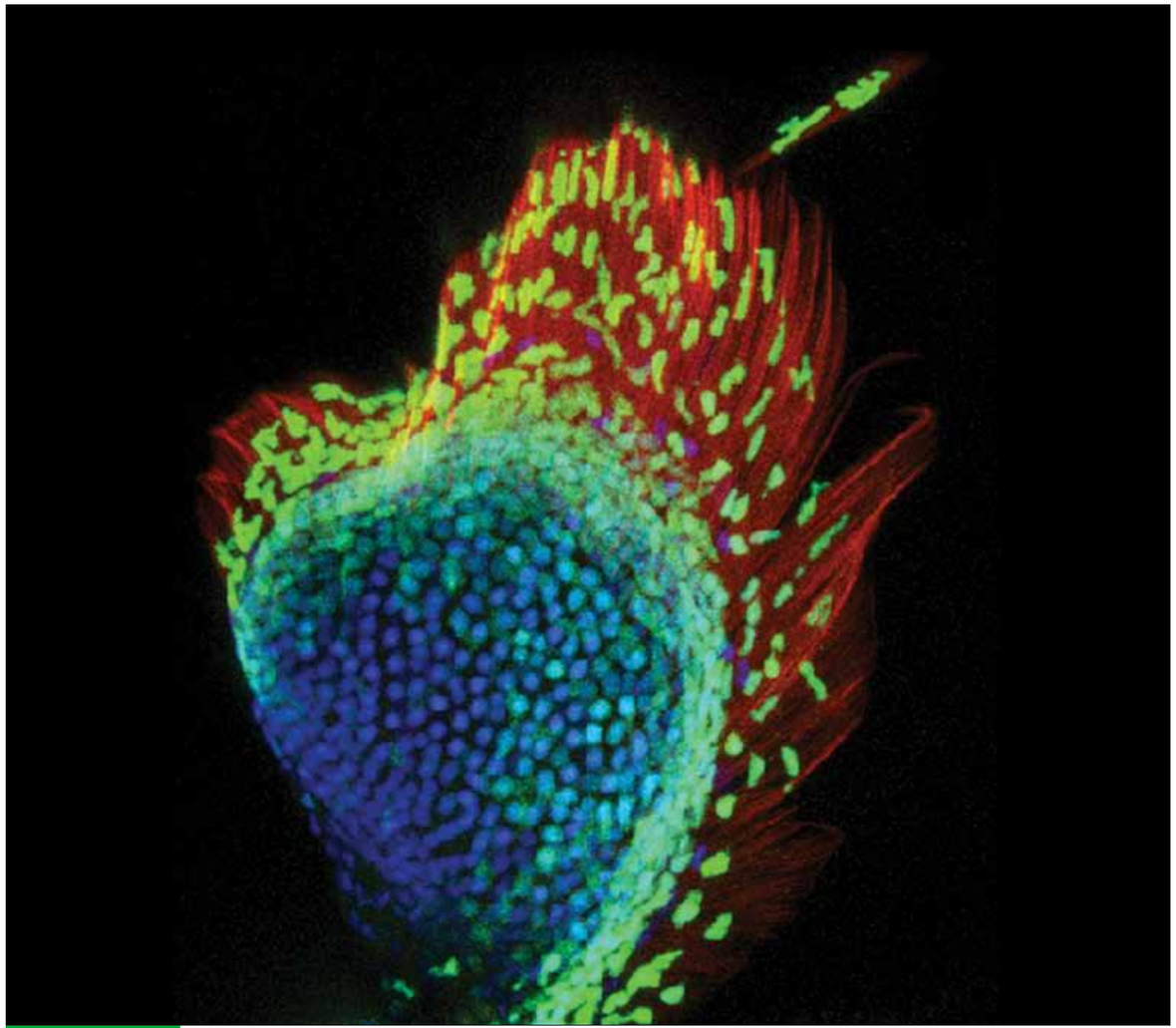
Methodology Semi-structured interviews with 44 boys and 38 girls between 13 and 18 years old via a range of agencies and organisations working with disadvantaged young people in south-west England. The research does not claim to be representative of the UK population, but suggests that levels of violence may be higher than previously assumed. 'Having a good rapport with interviewees is important. Wherever possible, Marsha Wood, who undertook most of the fieldwork, spent time getting to know the participants and gaining their trust.'

Main findings

- over half the girls and a quarter of boys reported physical partner violence
- two-thirds of girls and a third of boys reported emotional partner violence
- half the girls and a small minority of boys reported sexual partner violence
- most girls said their experiences had a negative effect on their wellbeing, while most boys were unaffected

Funder NSPCC

Summary www.nspcc.org.uk/inform



Portrait © Dan Rowley

In pictures

Dr Chrissy Hammond, Research Fellow in the School of Biochemistry, was one of the winners in the University's 2011 Art of Science competition with 'Finesse', an image of a zebrafish pectoral fin.

My research focuses on osteoarthritis, in particular on the genes that maintain cartilage condition – for example, stopping cartilage becoming mineralised like bone. I use zebrafish as a model system, partly because they lay large numbers of eggs that develop into translucent larvae, complete with muscles and head skeleton, about four days after fertilisation. Their translucency allows us to create detailed images of the cells in the cartilage, bone and muscle, which can be beautiful as well as informative.

In this instance, I was looking at collagen made by cartilage cells in the joints of the jaw when I noticed a stunning array of cartilage fibrils (stained red) in the fish fin. These extend out from the body of the fin (where the numerous cell nuclei are stained blue). Some cells (stained green) are programmed to become bone and cartilage cells. The arrangement is reminiscent of the patterns on peacock feathers.

The Art of Science is a creative arts competition for research scientists in the Faculty of Medical and Veterinary Sciences. Winning entries are displayed in the At-Bristol café until further notice. **bristol.ac.uk/fmvs/artofscience**

bristol.ac.uk