# RESEARCH HORIZONS

In this issue

## ENERGY & ENVIRONMENT

plus news and views from across the University

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A very warm welcome to the tenth issue of Research Horizons magazine.

The UK Government has recently unveiled its Low Carbon Transition Plan to move towards a permanent low carbon footing through cleaner and more efficient use of energy, and in this issue we look at how energy-related research in Cambridge is rising to this challenge of delivering a sustainable, secure and clean energy future. Much research is being directed at how we can reduce energy demand and improve energy efficiency, clean up energy generation from fossil fuels, develop new forms of renewable energy, and understand the policy frameworks that are needed to make it all work in practice. Do join us on 1 October at the Energy & Environment Horizon Seminar to hear first-hand from the individuals involved in these far-reaching research projects. Further details can be found on pages 7 and 35 of this issue.

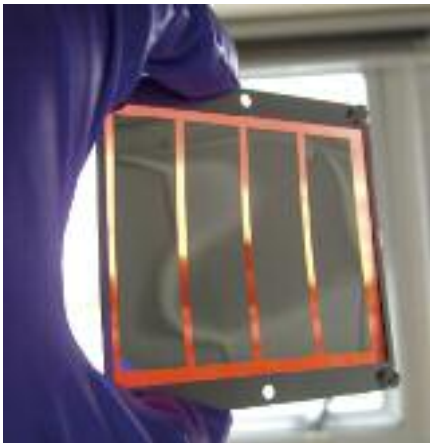
On our front cover are three newly appointed lecturers who are leading the research programme of the Energy Efficient Cities initiative: engineers Dr Steven Barrett (left) and Dr Ruchi Choudhary (centre) and architect Dr Ying Jin. This multidisciplinary initiative, which links over 30 researchers from seven departments, is focusing on the complex energy requirements of cities and how they can be reshaped.

But it's not all about energy… elsewhere in the magazine we look back to the time of medieval artists crafting pigments from 'dragonsblood'; back further to the early history and transmission of the Bible; and further still to the first moments of the Universe and the mission of the Planck satellite to understand some of the most important questions of modern science. These are just a few of the remarkable stories in this issue, for which we thank our contributors for the fascinating insight they've provided into their research.

If you have any comments and suggestions, please email them to me at research.horizons@rsd.cam.ac.uk

Louise Walsh

Dr Louise Walsh
Editor



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Cover photograph of Dr Steven Barrett (left), Dr Ruchi Choudhary (centre) and Dr Ying Jin.
Edited by Dr Louise Walsh.
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# Creative research on musical performance

**A pioneering research centre studying live musical performance as creative practice launches in the Faculty of Music in October with funding from the Arts and Humanities Research Council (AHRC).**

CMPCP

The five-year AHRC Research Centre for Musical Performance as Creative Practice (CMPCP) will address key questions about how musical performances take shape over time, how knowledge is transformed into practice in performance, and how understanding this creative practice varies across different traditions and cultures.

'Scholarly interest in musical performance has practically exploded during the last 20 years,' said Centre Director Professor John Rink. 'Whereas musicologists once understood music primarily in terms of notated texts, the experience of music in sound and through time, as well as the creative processes behind it, now inform research of the highest quality and urgency. Performance studies are at the top of the international research agenda – one which CMPCP will shape for years to come.'

A grant of £1.7 million from the AHRC has provided 'Phase 2' funding to establish the Centre in Cambridge in partnership with King's College London, the University of Oxford and Royal Holloway, University of London, and in association with the Guildhall School of Music & Drama and the Royal College of Music. CMPCP will build on the achievements of its predecessor, the AHRC Research Centre for the History and Analysis of Recorded Music (CHARM), which focused on musical recordings and was based at Royal Holloway.

Cambridge's contribution to the Centre will be spearheaded by Professor Rink, who will lead a project on creative learning and 'original' performance, and Professor Nick Cook, who is investigating music as creative practice. Professor Cook, who previously directed CHARM, was elected last year to the University of Cambridge's 1684 Chair of Music.

Cambridge is well placed to host CMPCP thanks to its outstanding performance environment. But as Professor Cook explained, its strengths as host institution go even further: 'Because music is a central feature of everyday life, its scope extends beyond the arts and humanities into the social and even the hard sciences. Cambridge's pre-eminence in all these areas, coupled with the possibility of creating working relationships between researchers in different disciplines, make it an ideal location to develop a musicology for the 21st century.'

**For more information, please contact Professor John Rink (jsr50@cam.ac.uk) or visit www.cmpcp.ac.uk/**

# Students give doctors a clear vision of invention potential

**A technique for testing the peripheral vision of young children could be given a boost – thanks to the inventors putting it into the hands of Cambridge students.**

KidzEyez is a new low-cost product designed to help gather accurate readings of toddlers' fields of vision. It was created by Dr Louise Allen, who is a paediatric ophthalmologist from Addenbrooke's Hospital and an Associate Lecturer at the University of Cambridge's Department of Medicine, and Dr Adar Pelah of York University.

The prototype device is a first in its field. Although similar products are used to measure the peripheral vision of adults, they are not suitable for small children. Dr Allen and Dr Pelah's invention could become a lifesaver as potentially serious neurological conditions such as tumours of the optic chiasm and pituitary gland can be picked up and treated earlier if visual-field loss can be detected, preventing permanent loss of vision and neurological deficit.

Now a group of research students is helping to formulate a plan to commercialise the product and market it to health providers. The students are part of the University of Cambridge i-Teams Programme, which brings together students from across the University to analyse the commercial potential of an emerging, breakthrough technology. The team was mentored by Cambridge business angel Bob Pettigrew and Dr Nikoletta Athanassopoulou of the Institute for Manufacturing.

'i-Teams has been an incredibly useful resource for us in the development of KidzEyez,' said Dr Allen. 'The team has been able to confirm a large potential market for KidzEyez and enabled me, as a clinician, to understand the principles and practicalities of marketing the device.'

**For more information about i-Teams, please contact i-Teams Programme Director Amy Mokady (am678@cam.ac.uk; www.iteamsonline.org/); for more information about KidzEyez, please contact Dr Louise Allen (louise@louiseallen.com).**

# Recharging energy research

## A new phase of research harnessing materials for rechargeable batteries is beginning in the Department of Chemistry.

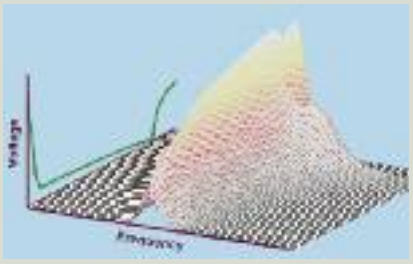
Laboratory refurbishment has commenced in readiness for a new programme of research on energy materials under the leadership of Clare Grey, the newly elected Geoffrey Moorhouse Gibson Professor of Chemistry. For the past 15 years, Professor Grey has led a research team at Stony Brook University, New York, investigating materials for energy storage and conversion.

Professor Grey's particular focus among energy materials is electrodes for lithium-ion batteries. These lightweight and energy-dense materials have provided one of the most important recent breakthroughs in batteries used for consumer electronics, and are increasingly being considered by the automotive industry to power hybrid and electric vehicles, and for load levelling to manage the flow of electricity in a power grid.

'To expedite the use of lithium-based materials in energy-efficient applications, there are some significant fundamental challenges relating to lithium chemistry that need to be overcome,' said Professor Grey. 'Our research is aimed at a better understanding of how lithium batteries work, and how to recharge them faster, for longer and more safely.'

One component of Professor Grey's research is to develop new tools based on nuclear magnetic resonance (NMR) for visualising how ions are transported through the different materials in real time and to use this information to feed into the design of the next generation of batteries. The laboratory, which will incorporate a new solid-state NMR machine, has received funding from the Royal Society and the Engineering and Physical Sciences Research Council (EPSRC).

The opportunity of being part of Cambridge's energy research agenda is an important draw for Professor Grey: 'I am very excited about the prospect of building a programme aimed at having significant impact in some of the key areas where solutions are needed in energy technology,' she said.



PROFESSOR CLARE GREY

**Using NMR to investigate changes in local structure during electrical discharge in a lithium-ion battery**

Professor Jeremy Sanders, Chair of the School of Physical Sciences, added: 'We are delighted to welcome Professor Grey, whose appointment not only brings an important new dimension to materials chemistry in the Department, but also represents a commitment to building research in the area of energy.'

**For more information, please contact Professor Clare Grey (cpg27@cam.ac.uk).**

# Clean technology cleans up

## Despite the economic downturn, four University spin-out clean tech companies have received over £12 million in funding.

The four companies – Enecsys, Metalysis Limited, Enval and Camfridge – are part of a growing portfolio of clean tech companies in which Cambridge Enterprise Limited holds equity on behalf of the University as a result of licensing intellectual property and direct cash investments. Clean technology describes products or processes that balance high productivity and efficiency with reduced energy consumption, costs and pollution; the Cambridge Enterprise portfolio now includes nine clean tech companies, with more in the pipeline.

The four recent recipients of new funding are:

**Enecsys**, a spin-out from Professor Gehan Amaratunga's research in the Department of Engineering, which has raised $10 million in a Series A funding round. The funds will be used to speed up commercialisation of the micro-inverters developed to convert the energy gathered by solar modules from DC to much more useable AC.

**Metalysis Limited**, a spin-out from Professor Derek Fray's research in the Department of Materials Science and Metallurgy, which has raised £5.1 million to develop its environmentally friendly method to produce tantalum and titanium metals and alloys. The funds will mainly be used to support the scale-up of a novel semi-continuous pilot plant.

**Enval**, a spin-out from research by Dr Carlos Ludlow-Palafox and Professor Howard Chase in the Department of Chemical Engineering, which has developed a pilot plant for environmental recycling technology specifically for laminated packaging waste. Enval recently completed its Series A round of funding led by IQ Capital and other investors including Cambridge Enterprise and members of the Cambridge Angels and Cambridge Capital Group.

**Camfridge**, a spin-out from research by Professor Derek Fray and Dr Karl Sandeman in the Department of Materials Science and Metallurgy, which is developing a platform for use in key target applications in eco-refrigeration and has received R&D grants from the Carbon Trust and the European Union.

**For more information on the clean tech portfolio held by Cambridge Enterprise Ltd, please contact Nick Slaymaker (nick.slaymaker@enterprise.cam.ac.uk), Investment Manager, Cambridge Enterprise Seed Funds, or visit www.enterprise.cam.ac.uk/**

cambridge enterprise
commercialising University science

# Voices of vanishing worlds

## A new project is recording and making accessible the endangered oral literatures of indigenous peoples before they are lost forever.

SARA SHNEIDERMAN

**Recitation of oral texts by Latte Apa, senior ritual practitioner of the Thangmi community, Darjeeling, India**

The World Oral Literature Project has recently been established to support the collection of oral literature by funding, training and working with local communities and fieldworkers who are engaged in documentation projects.

For many communities around the world, the transmission of oral literature from one generation to the next lies at the heart of cultural practice. These creative expressions may be ritual texts, curative chants, epic poems, folk tales, songs, word games, life histories or historical narratives. However, globalisation and socio-economic change exert complex pressures on smaller communities, eroding expressive diversity and transforming culture through assimilation to more-dominant ways of life. Of the world's 6,000 natural languages, as many as half will probably not survive for another generation. As vehicles for the transmission of unique cultural knowledge, languages are repositories of oral traditions that become threatened when elders die and livelihoods are disrupted.

Dr Mark Turin, who leads the project, which is associated with the Museum of Archaeology and Anthropology, explains its importance: 'It's often the vernacular traditions of communities living on the margins of nation states that are most at risk. By supporting communities to document their own cultures for the future, and through working with engaged and committed scholars, our project is responding to this urgent challenge.'

With initial funding from the Firebird Foundation for Anthropological Research, the Onaway Trust and the Chadwyck-Healey Charitable Trust, the first phase of the project is under way. A digital repository of oral literatures from around the world has been launched, as has the first tranche of supplemental funding for fieldwork projects, including the recording of folk music of Lo Monthang, Nepal, and ceremonial chanting in the Vaupés Region of Colombia. A training workshop at the Centre for Research in the Arts, Social Sciences and Humanities (CRASSH) will run in December, bringing together scholars, indigenous researchers, curators and archivists.

In a remarkable cross-disciplinary research collaboration, the project is also working with zoologist Bill Sutherland, the Miriam Rothschild Professor of Conservation Biology at Cambridge, to develop a consolidated database on endangered cultures, languages and ecology at a global level. 'While the World Oral Literature Project has been forming in our minds for some time, only by collaborating with colleagues and coordinating resources and expertise can we hope to document the voices of these vanishing worlds,' explained Dr Turin.

The pilot project is currently seeking sustainable long-term funding to make it a permanent fixture in the University's research agenda.

**For more information, please contact Dr Mark Turin (mt10003@cam.ac.uk) or visit www.oralliterature.org/**

# Open Access in Cambridge

## The University of Cambridge's first Open Access Week will enhance knowledge and understanding of the Open Access phenomenon.

The Open Access movement worldwide has been gathering pace as top-tier universities embrace the effort to provide free online access to research literature and data. To support understanding of Open Access, the University Library is organising a number of events in October during the International Open Access Week. The events are built around DSpace@Cambridge (www.dspace.cam.ac.uk/), the University's institutional Open Access repository.

'Increasingly, research funding agencies and universities are viewing Open Access as an effective way of ensuring the greatest possible impact for the research they fund,' explained Barbara Bültmann, DSpace's Support and Liaison Officer and one of the organisers of the conference. 'All seven UK Research Councils expect research they support to be available on Open Access and the majority of UK universities have institutional repositories like DSpace@Cambridge to provide managed environments for sharing their digital research output.'


Open Access literature is digital, online, free of charge, and free of most copyright and licensing restrictions. By publishing in Open Access journals, or through placing copies of material in Open Access repositories, authors maximise their research impact and increase the visibility of their data, which are then used, cited and built upon, ultimately furthering the research itself.

**Find out more about Open Access by visiting one of the events in Cambridge during the first International Open Access Week on 19–23 October 2009 (www.lib.cam.ac.uk/create_change/events.html).**

# Broers Building available soon!

**A new opportunity will shortly be available for companies wishing to be part of Cambridge's premier science and innovation cluster.**

**The Broers Building alongside the new Hauser Forum**

A prestigious new building on the West Cambridge Site is on target for completion well ahead of the year end, providing a good opportunity for R&D-intensive businesses to co-locate in a very exciting new environment. Named in honour of the former University of Cambridge Vice-Chancellor Lord Broers, the Broers Building will provide a pioneering centre for research collaboration for emerging SMEs and international companies working with the University.

The Broers Building is part of a new development by Turnstone Estates and the University. The development will enable companies involved in, and supporting, the University's commercialisation activities to work in closer partnership with Cambridge Enterprise Limited, which will be located in the adjacent Hauser Forum, as well as with the growing number of academic researchers located at West Cambridge.

Already located on site are the University's Cavendish Laboratory, Whittle Laboratory, Computer Laboratory, Centre for Advanced Photonics and Electronics, and Nanoscience Centre, as well as the Institute for Manufacturing and the Department of Veterinary Medicine. This cluster of prestigious research facilities, together with the increasing number of University collaborations in West Cambridge with commercial organisations such as Microsoft, Nokia, Hitachi and Schlumberger, has strengthened Cambridge's position as Europe's leading centre for entrepreneurial science-based business.

**Businesses interested in leasing space are invited to contact Jonathan Burroughs (jonathan.burroughs@creativeplaces.com or 01223 559347) or visit www.broersbuilding.co.uk/**

# EU boost for obesity research

**Cambridge will play a major role in a new European research consortium studying molecular mechanisms that give rise to obesity.**

The 'EurOCHIP' consortium, which launches in November, brings together experts from seven European institutions to investigate how signals from the gut communicate with the brain to control appetite. The project has been awarded €3 million from the European Union Seventh Framework Programme and is being coordinated by Dr Giles Yeo from the University of Cambridge Metabolic Research Laboratories (MRL) and the Medical Research Council (MRC) Centre for Obesity and Related metabolic Diseases (MRC CORD).

Obesity is widely accepted to pose one of the greatest public health challenges we currently face. Already it is responsible for up to 8% of health costs and 10–13% of deaths throughout Europe – and these figures are likely to increase significantly in the coming years if the rising incidence of the disease continues unchecked.

The EurOCHIP project will undertake multidisciplinary studies to better understand how different diets affect the secretion of gut hormones and how the brain responds to these hormones to regulate appetite, energy expenditure and, ultimately, body weight.

'In order to effectively tackle the problem of obesity, we need to better understand the biology that underlies the control of food intake and bodyweight,' explained Dr Yeo. 'We hope that EurOCHIP will go some way to achieving this goal, thereby having an impact on the development of effective new strategies to prevent and treat obesity.'

**For more information, please contact Dr Giles Yeo (gshy2@cam.ac.uk).**

# Cambridge to host genetic research hub

**Cambridge is one of four 'hub' universities receiving funding for high-throughput sequencing machines.**

The Medical Research Council (MRC) is investing over £9 million in supporting fundamental genetics research by creating four high-throughput sequencing (HTS) hubs in Scotland (Edinburgh), Oxford, the North of England (Liverpool) and the East of England (Cambridge), giving every gene scientist across the UK access to state-of-the-art equipment for DNA sequencing.

The creation of the Eastern Sequencing and Informatics Hub (www.easih.org/), hosted by the University at the Cambridge Biomedical Campus, Addenbrooke's Hospital, will enable researchers working in the region to take advantage of the latest research technology. It will be part of a collaboration with the European Molecular Biology Laboratory's European Bioinformatics Institute, the Babraham Institute, the National Institute for Health Research (NIHR) Cambridge Biomedical Research Centre, and the next-generation sequencing technology companies Roche-454, Illumina and Life Technologies.

One of the hubs' Principal Investigators, Professor John Todd, from the Department of Medical Genetics and the Cambridge Institute for Medical Research, said: 'Only a few years ago, it took an international consortium many years of effort to produce a first draft of the human genome sequence, but now it will be possible for the hub in Cambridge to sequence 100 human genomes in a year.'

**For more information, please visit www.easih.org/**



# Energy & Environment

**To introduce our Spotlight section on Energy & Environment, Professor Dame Ann Dowling describes the strength of Cambridge's research portfolio in this area. The University will be showcasing this research at a Horizon Seminar on 1 October.**

One of the greatest challenges facing mankind is how to deliver our energy requirements sustainably and securely without damaging the environment.

Addressing this challenge is an area of intense activity within Cambridge, resulting in several pan-University collaborations that have developed around key themes of energy demand reduction, energy supply and energy policy, embedded within an overall framework for sustainability. The value of the University's current portfolio of energy-related grants is £100 million. In the Department of Engineering alone, the figure is £30 million, with 50% of that funding coming from industry. Much of the University's energy-related research is linked to international collaborations with the USA, European Union, India and China.

Reducing energy demand and increasing energy efficiency are significant drivers for research today. In the UK, buildings account for approximately 40% of the demand for energy (excluding the embedded energy of construction materials), and ground transportation uses another 27%. Ways of heating and cooling buildings more efficiently are being investigated in several departments in Cambridge and are being exploited in building designs. Reducing our energy consumption from lighting is also important, and has led to the development in Cambridge of materials that emit light with high efficiency. A multidisciplinary study in Cambridge is analysing the effect of these and other new technologies by taking a systems-level approach to the complex optimisation of towns and cities. Other studies are tackling ways in which materials can be produced more efficiently, because as much as 20% of global greenhouse gas emissions from using energy arise in the production of five key materials: cement, steel, plastic, paper and aluminium.

Various forms of renewable energy are being developed at Cambridge, from biofuels, through wind and wave power, to photovoltaic cells. The power conversion electronics for connecting solar cells to networks is also being studied, as are the planning and grid stability implications of distributed micro-generation combined with more nuclear power. Within the University, we are finding tremendous interest from undergraduates in our courses on nuclear engineering and materials, and research activities in areas to support the building of new nuclear power stations are growing fast.

Renewable energy has a vital role in the diversification of energy supply, but for the foreseeable future most of our electrical power will continue to come from fossil fuels. The clean use of fossil fuels depends on research efforts such as those that are developing ways to burn coal and separate $CO_2$ in the exhaust, ready for sequestration.

Addressing these challenges requires the development of not only new technologies but also policies and pricing strategies to encourage their adoption. Energy policy research is an active area at Cambridge, bringing together researchers in economics, business and many other fields through the Electricity Policy Research Group and the Cambridge Centre for Energy Studies.

There will be no single solution to the challenge of balancing energy requirements and the environment. Instead, a combination of changes in technologies, policies and practice will be needed. Researchers at Cambridge are fully involved in bringing about these changes.

**Professor Dame Ann Dowling**

**Professor Dame Ann Dowling is at the Department of Engineering.**

**The Horizon Seminar takes place at the Centre for Mathematical Sciences, Cambridge, on 1 October 2009. For more information and to book online, please visit www.rsd.cam.ac.uk/events/energyandenvironment/**

## Participating speakers and chairs

HORIZON

**Dr Julian Allwood**, Department of Engineering
**Professor Dame Ann Dowling**, Department of Engineering
**Professor Neil Greenham**, Department of Physics
**Professor Peter Guthrie**, Department of Engineering
**Professor Chris Howe**, Department of Biochemistry
**Tim Longstaff**, WS Atkins plc
**Professor David MacKay**, Department of Physics
**Professor Robert Mair**, Department of Engineering
**Professor David Newbery**, Faculty of Economics
**Dr Glenn Vinnicombe**, Department of Engineering

# Energy Efficient Cities initiative

***'Cities… embody the environmental damage done by modern civilization; yet experts and policymakers increasingly recognize the potential value of cities to long-term sustainability. If cities create environmental problems, they also contain the solutions.'***
**United Nations Population Fund**

Today, more than half of the world's population, over 3.3 billion people, live in urban areas; a figure that, according to current predictions, may rise to 5 billion by 2030. Economic growth goes hand-in-hand with urbanisation, but this leads to an increasing demand for energy and a rising environmental impact. Taking the UK as an example, the buildings and ground transportation in urban areas (in which 80% of the population currently lives) account for approximately two-thirds of the country's current total energy demands. Clearly, large benefits are to be gained from addressing the challenge of improved energy efficiency in towns and cities.

Cambridge's Energy Efficient Cities initiative (EECi) is working towards this vision – aiming to strengthen the UK's capacity to address energy demand reduction and environmental impact in cities through cross-disciplinary research that embraces building and transport technologies, district power systems and urban planning.

The five-year interdisciplinary collaboration is being funded by £2.9 million from the Engineering and Physical Sciences Research Council (EPSRC) under a Science & Innovation Award. This joint effort brings together over 30 researchers (see panel) under the leadership of Professor Ian Leslie (Principal Investigator and Pro-Vice-Chancellor for Research), Professor Dame Ann Dowling and Professor Robert Mair at the Department of Engineering, and Professor Marcial Echenique and Professor Koen Steemers at the Department of Architecture.

## A complex system

Cities can be thought of as integrated systems composed of numerous components with interconnecting links. Into the complex equation of analysing energy efficiency in cities must be factored variables such as the density, layout and types of buildings, the transport requirements, the location of green spaces and the proximity of local forms of power generation.

'Cities are complex systems,' explained Professor Leslie. 'Even individual issues such as environmental impact, transport, quality of life and economic growth are themselves complex, let alone their interaction. Devising practical and realistic proposals for how cities can be reshaped can only be achieved through a holistic, cross-disciplinary approach.'

To achieve this, EECi has devised a systems-level approach that brings together technologies and design (of buildings, transport and energy), impacts and assessment (of the environment, and of society and the economy) and city-level integration of planning and design. Three new lecturers appointed through the EPSRC award are leading the research modules: Dr Ruchi Choudhary and Dr Steven Barrett from the Department of Engineering and Dr Ying Jin from the Department of Architecture.

## Technologies and design

A distinctive feature of research on the technologies and design of buildings will be the development of feasibility metrics for implementing suitable technologies that improve the environmental conditions and lower the operating utility costs of buildings, both domestic and commercial. This will require an expanded representation of geographical, physical and behavioural inputs in building energy models. The scope of the work will span urban design strategies for reducing energy use and carbon emissions in cities, as well as more-detailed investigations of enabling technologies.

A very significant proportion of the built environment is influenced by the need for mobility. Currently, vehicle performance, in terms of acceleration, top speed, size and weight, far exceeds that needed in an urban environment – a situation that has been driven partly by customer preference and partly by crash-worthiness. Research on transport will consider the options for innovations: could, for instance, the transition to electric cars improve air quality and lead to more 'open' city centres with improved public places and natural ventilation within large office and commercial buildings? Would there be climate change trade-offs in doing this? And what would be the impact of 'smart charging' of electric cars on overall energy consumption and building design?

The UK Government's new Low Carbon Transition Plan has reinforced its commitment to increase its renewable energy capacity to cover 30% of energy


consumption by 2020. Research in the Energy module of EECi will assess the feasibility and environmental benefits of district power systems and alternative energy supply technologies on different building configurations and geographical scales. 'We know that the feasibility of using energy supply systems is in principle influenced by physical and geographical characteristics of the context in which they're used,' explained Dr Choudhary. 'Imbalances between total supply and demand, and variations in the building's heat capacity and demand variability resulting from seasonal cycles, can be critical.'

## Impacts and assessment

Designing the most efficient and sustainable cities must be balanced with economic and social impacts: after all, cities need to be comfortable and cost-effective to live in. 'We need to quantify the impacts of technology and policy measures upon society and the economy for a variety of settlement designs,' said Dr Jin. 'Only then can we hope to work out realistically how good they are.'

Similarly, assessments of environmental impact are crucial: 'It's no good designing energy-efficient approaches that have a net negative impact on global climate, or that result in poor air quality,' explained Dr Barrett. 'Monitoring the impact of the urban microclimate and translating this into public health and environmental effects is fundamental to assessing which technological scenarios will work.'

## City-level integration

To solve the challenges posed by integrated systems that have the complexity and scale of cities, a systems-level approach must combine economic, technical and design ideas with macro-economic trends, demographic projections and environmental data.

The intention of EECi is to combine these criteria into a coherent computer model calibrated on real data. Not only does this enable a more robust scaling up of the impact of technological innovations at the city level, but it also allows the assessment of different trade-offs between the environmental, societal and economic impacts. This helps to inform regulators and policymakers. How, for instance, can the planning of land use in city regions be coordinated with significant land requirements for generating renewable energy? What alternatives are there in building forms and density that reduce the impact on energy use for travel and activities within an urban environment?

The EECi models will represent not only geographical patterns of land use and physical built forms, but also business and household activities and their responses to policy and technological change. The models will cover both new development and the retrofit of existing urban areas, and will therefore be relevant to a much wider technology and policy context than it has been possible to envisage previously.

The goal is to use insights gained from urban models to inspire new technological, planning and design solutions, both in cities of the developed world, where the bulk of the building stock is already complete, and in cities of the developing world, where some cities may double or triple in size in the next 30 years.

**Dr Steven Barrett (left), Dr Ying Jin (centre) and Dr Ruchi Choudhary**

**For more information, please contact Dr Steven Barrett (steven.barrett@eng.cam.ac.uk) and Dr Ruchi Choudhary (r.choudhary@eng.cam.ac.uk) at the Department of Engineering, and Dr Ying Jin (yj242@cam.ac.uk) at the Department of Architecture, or visit www.eeci.cam.ac.uk/**

## Collaborators in the EECi

**Department of Engineering**: Professor Dame Ann Dowling, Professor Robert Mair, Dr Ruchi Choudhary, Dr Steven Barrett, Professor Nick Collings, Professor Randall Thomas, Professor Peter Guthrie, Dr Heather Cruickshank, Dr Alan McRobie, Dr Mauro Overend, Professor John Young, Professor Simone Hochgreb, Professor Epaminondas Mastorakos, Dr Alex White, Dr Stuart Scott, Dr Matthew Juniper, Dr Holger Babinsky, Professor Gehan Amaratunga, Dr Richard McMahon, Dr Patrick Palmer, Dr Claire Barlow

**Department of Architecture**: Professor Marcial Echenique, Professor Koen Steemers, Dr Ying Jin, Professor Alan Short, Michael Ramage, Dr Torwong Chenvidyakarn, Dr Minna Sunikka

**Department of Chemical Engineering and Biotechnology**: Dr John Dennis

**Computer Laboratory**: Professor Andy Hopper, Professor Ian Leslie, Dr Andy Rice, Professor Jean Bacon

**BP Institute**: Professor Andy Woods, Dr Shaun Fitzgerald

**Department of Materials Science and Metallurgy**: Professor Colin Humphreys

**Judge Business School**: Dr Bill Nuttall, Cambridge Centre for Energy Studies, Dr Theo Hacking

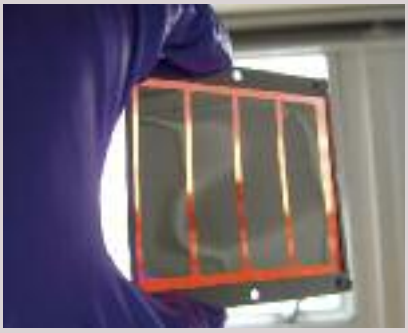
**Plus over 15 external collaborating companies**

# Organic solar cells

PROFESSOR SIR RICHARD FRIEND (BOTH IMAGES)

**Solar cells can now be manufactured by roll-to-roll printing**

**How can the cost of solar cells be reduced enough to make them a feasible source of large-scale renewable energy? The answer is to make them thin.**



**Prototype solar cell panel**

Research that began at the Cavendish Laboratory in the Department of Physics, and now draws in departments from across the University, has discovered how to make lightweight, flexible and cheaper photovoltaic ('solar') cells. This technology unlocks new potential to deploy vast areas of solar cells that will be needed as part of the renewable energy portfolio when we move away from fossil fuels.

## Converting light energy to electricity

Solar cells use semiconductors to capture light. Each photon of light that is absorbed raises an electron in the semiconductor material to a high-energy state. The electron then drifts away from the net positive charge left behind (termed a 'hole') and this generates a current, which is drawn off as electricity.

Silicon makes excellent solar cells – it's the right colour, absorbing across the visible and near infrared parts of the solar spectrum, and makes reasonably efficient cells. However, its efficiency has limitations: for silicon to absorb enough light, relatively thick slabs (typically 0.2 mm) need to be used. Semiconductor-grade silicon is an expensive material, too expensive to make the scale-up of silicon-based solar panels a feasible prospect.

## New materials roll up

A worldwide search has been under way during the past decade to find other semiconducting materials that may provide cheaper solar cells. If we are to reduce the cost of deployment, we need to bring down the cost not just of the semiconductor materials used in the solar cell itself, but also of all the other materials used in the solar cell assembly, such as the substrate and how it is encapsulated in the panel.

The best solution might be to print the entire apparatus – the active semiconductor layers, metal electrodes and tracks – directly onto a plastic film. And the fastest way to do this would be to use continuous roll-to-roll printing, in much the same way that newspapers are printed. Solar cells manufactured in this way would be lightweight, flexible and, crucially, much cheaper and easier to deploy than current systems enclosed within glass sheets.

Roll-to-roll printing sets us some big challenges. It requires scientists to develop a completely new materials set, re-design the solar cell semiconductor architecture and build up the manufacturing skills that allow precise control of printed film thickness. Within the University, we now have a broad programme of science and engineering to cover this full set of research tasks: Professor Sir Richard Friend,

Professor Neil Greenham, Professor Henning Sirringhaus, Dr Chris McNeill and Professor Ulli Steiner in the Cavendish Laboratory; Professor Wilhelm Huck in the Department of Chemistry; Professor Mark Welland and Dr Andrea Ferrari in the Department of Engineering; and Professor Judith Driscoll in the Department of Materials Science and Metallurgy.

## Persuading electrons to leave home

Roll-to-roll printing requires semiconductor materials that can be handled as 'inks' and printed at room temperature – a very different world from the traditional high-temperature and high-vacuum processing world of silicon technology. One very attractive set of materials are the polymeric organic semiconductors that Professors Friend, Greenham and Sirringhaus have developed for use both in light-emitting diodes (exploited through the University spin-out company Cambridge Display Technology Ltd) and in printed transistors for electronic paper displays (under development by another spin-out, Plastic Logic Ltd). There is however a catch. While silicon readily liberates electrons from holes when a photon is absorbed, the excited electron generated in an organic semiconductor is very reluctant to leave its positively charged hole.

Nature has already solved this problem in plants: in photosynthesis, the excited electron is generated at the interface between two semiconducting molecules that have different electron affinities. This causes the electron to move to the adjacent molecule, leaving the hole behind. Subsequent steps in photosynthesis use the reducing power of the electron and the oxidising power of the hole to complete the chemistry.

For solar cells, we have the simpler task of arranging that the separated electron and the hole can be collected at their respective electrodes to either side of the device. Although it was discovered some time ago by the researchers at the Cavendish Laboratory that single interfaces (or heterojunctions) seem to function reasonably well, the electron would often move no further than to the adjacent site across the heterojunction, bound by its electrostatic attraction to the positively charged hole. Although this creates a current, the efficiency of energy conversion is limited.

The Cavendish group, together with Professor Huck in the Department of Chemistry and colleagues at Imperial College London, are just beginning work to tackle this problem, funded by a major Engineering and Physical Sciences Research Council (EPSRC) Programme Grant (£6.8 million over five years). A significant programme of chemical synthesis, materials processing and semiconductor physics measurements aims to develop more-controlled heterojunctions that will be better at moving the two charges away from one another. The goal is to raise energy conversion efficiencies from current levels of around 5% to at least 10%, making the technology competitive with other solar cell technologies – a big challenge but one that the multidisciplinary group of researchers believes is attainable.

## Grand challenges at the nanoscale

We face a second challenge: the excitation produced by the absorbed photon needs to find its way to the heterojunction before it decays. It is usually short-lived (about 1 nanosecond) and cannot therefore travel very far, typically about 10 nm (i.e. 20 or so intermolecular spacings). However, we need much greater thicknesses of semiconductor to absorb all incident light. The solution that is being investigated worldwide is to arrange that the electron-accepting and hole-accepting materials form an inter-penetrating network with dimensions at this nanometre lengthscale. Not only does this need to give efficient charge separation, but it also needs to allow the electrons and holes to move along continuous pathways to the electrode – a by no means trivial set of requirements!

One very promising route is to use polymers composed of two blocks of chemically distinct polymers (diblock copolymers). When the two blocks are selected so that they repel one another, they form very specific ordered structures with regions of one block tied to regions of the other block by the chemical bond that links them. The researchers are developing these nanostructures in a programme supported by a £1.3 million EPSRC grant under the Nanotechnology Energy Grand Challenge programme, which draws on Professor Steiner's polymer expertise, together with Professor Huck's synthesis expertise and continuing developments in solar cell research at the Cavendish. This and related approaches are facilitating the use of inorganic semiconductors such as titanium dioxide and zinc oxide to form nanocrystalline frameworks that can be subsequently filled with organic semiconductors; these structures are being developed by Professors Welland and Driscoll in their respective research groups.

## Towards manufacturing

The programme of work on the process engineering of the printed solar cell has been positioned to provide the best interface between research and its move to industry. Cambridge's EPSRC-supported Integrated Knowledge Centre has been used to start the printing project. This has also brought in Dr Ferrari's work in Engineering on conducting carbon nanotube and graphene electrodes. Together with the technology and product development company The Technology Partnership, the researchers bid for and won a competition run by the Carbon Trust in 2007 to set up an industrial activity to prove the manufacturability of new solar cell technologies. With a commitment of £5 million from the Carbon Trust, the printing activity is growing rapidly, and large-scale solar power has now become a possibility that is within our grasp.

PHIL MYNOTT

**Professor Sir Richard Friend**

**For more information, please contact the author Professor Sir Richard Friend at the Cavendish Laboratory in the Department of Physics (rhf10@cam.ac.uk).**

# Towards a smarter electricity future



Drax Power Station

**The Electricity Policy Research Group – a programme that spans the Faculty of Economics and Judge Business School – is providing world-class analysis to support an evolving electricity industry.**

Global efforts to address climate change will involve the massive roll-out of existing low carbon energy technologies as well as the development of new technologies, together with increased energy efficiency, fundamental behavioural shifts, and processes that will reduce carbon emissions, all on an unprecedented scale. Such change requires smart engineers, willing industries and green consumers. But it also requires getting the regulatory framework structures and policies right at national and international levels.

A better understanding of these incentives and policies forms part of the work of the Electricity Policy Research Group (EPRG), along with analysis of liberalised energy markets, and pricing carbon via taxes or emissions trading. This joint research programme between the Faculty of Economics and Judge Business School was launched in 2005, when the EPRG was awarded a five-year, £2.38 million grant from Research Councils UK (RCUK), expanding on the work of the Cambridge-MIT Institute Electricity Project.

Professor David Newbery, Director of the EPRG, leads a group that now numbers more than 30 researchers, including a team of 12 faculty and senior research staff, together with PhD students and Associates from departments across Cambridge and other leading institutions. The research team is built around core expertise in economics and policy, with active collaboration between experts from different academic traditions, and draws on insights from engineering, political science and law. The group is also supported by the industry and government sponsors of its Energy Policy Forum, which helps leverage research funding and enhances the EPRG's ability to respond to important research questions as they arise.

Two recently completed EPRG research projects (see panels) exemplify the types of analyses that are helping the electricity industry evolve: the risks and incentives for taking forward carbon capture and storage (CCS), and the opportunities for increasing energy efficiency through smart metering, both of which are key elements in the UK's new Low Carbon Transition Plan.

**Dr Michael Pollitt (left), Professor David Newbery (centre) and Dr David Reiner**

**For more information, please contact the authors Dr David Reiner (d.reiner@jbs.cam.ac. uk) and Dr Michael Pollitt (m.pollitt@jbs.cam.ac.uk) at Judge Business School and Professor David Newbery (dmgn@econ.cam.ac.uk) at the Faculty of Economics or visit www.eprg.group.cam.ac.uk/**

## Carbon capture and storage (CCS): risks and incentives

### A study sponsored by the UK Department of Energy and Climate Change has analysed the incentives needed to reduce emissions from fossil-fired electricity generation.

The idea behind CCS is to capture the $CO_2$ emitted from power plants burning fossil fuels and to store it safely in geological formations such as depleted oil fields. By 2015, the European Union (EU) aims to have up to 12 commercial-scale CCS demonstration projects deployed across Europe, but as of today there are still no commercial projects operating and each project is expected to cost hundreds of millions of pounds.

With so much at stake, a competition has been launched by the UK Government to build one of the world's first commercial-scale CCS power plants in the UK. This was followed by recent announcements of support for CCS at the level of the EU, and a UK Government commitment of up to four demonstration plants. But how to select the projects? A study led by Dr David Reiner and Professor David Newbery set out to identify the key risks in designing the project selection process and to examine the interactions between incentives for CCS at the EU level and those at the national level.

### Getting the incentives right

Bringing together experts on auction design, game theory and R&D policy, the study examined European support schemes in greater detail. In addition to stimulus spending of over €1 billion (up to €180 million per project), the EU has earmarked 300 million allowances under the EU Emissions Trading Systems to support CCS and innovative renewables technologies (up to 45 million allowances per project). Several risks were identified in designing the project selection process, including the carbon price risk, the variable cost risk, the technological risk and inefficiencies such as the effect of firms colluding or possessing information unavailable to governments. To overcome these concerns, a Technology Category Auction was proposed that would deliver learning from diversity (validation of the main available technological options) rather than learning by doing.

The hope is that research such as this can help governments put in place policy frameworks at national and international levels that will enable the CCS demonstration phase to be conducted in a manner that is both effective, by demonstrating a range of CCS technologies across Europe, and accomplishes it at least cost.

## Examining the prospects for smart metering

### Could smart meters be the answer to promoting efficient, flexible and sustainable energy consumption?

Decarbonising the electricity system is just part of the story. Achieving the UK's target of an 80% reduction in greenhouse gas emissions below 1990 levels by 2050 will involve perhaps as much as a 50% or more improvement in energy efficiency relative to business as usual. A key part of any climate change strategy therefore is to change the nature of the relationship between the energy services that people need and the amount of energy that is supplied. One mechanism for delivering this is the so-called smart electricity meter – a two-way real-time communication between the household and the electricity grid that enables demand to be varied in response to available supply.

The UK Government is currently in a two-year consultation period prior to announcing its strategy for how to roll out smart meters to all households by 2020 in line with the EU Energy Services Directive. Dr Michael Pollitt and colleagues Dr Tooraj Jamasb and Aoife Brophy Haney in the EPRG have been examining the prospects for smart meters in the light of international roll-outs that have already occurred.

### From dumb to smart

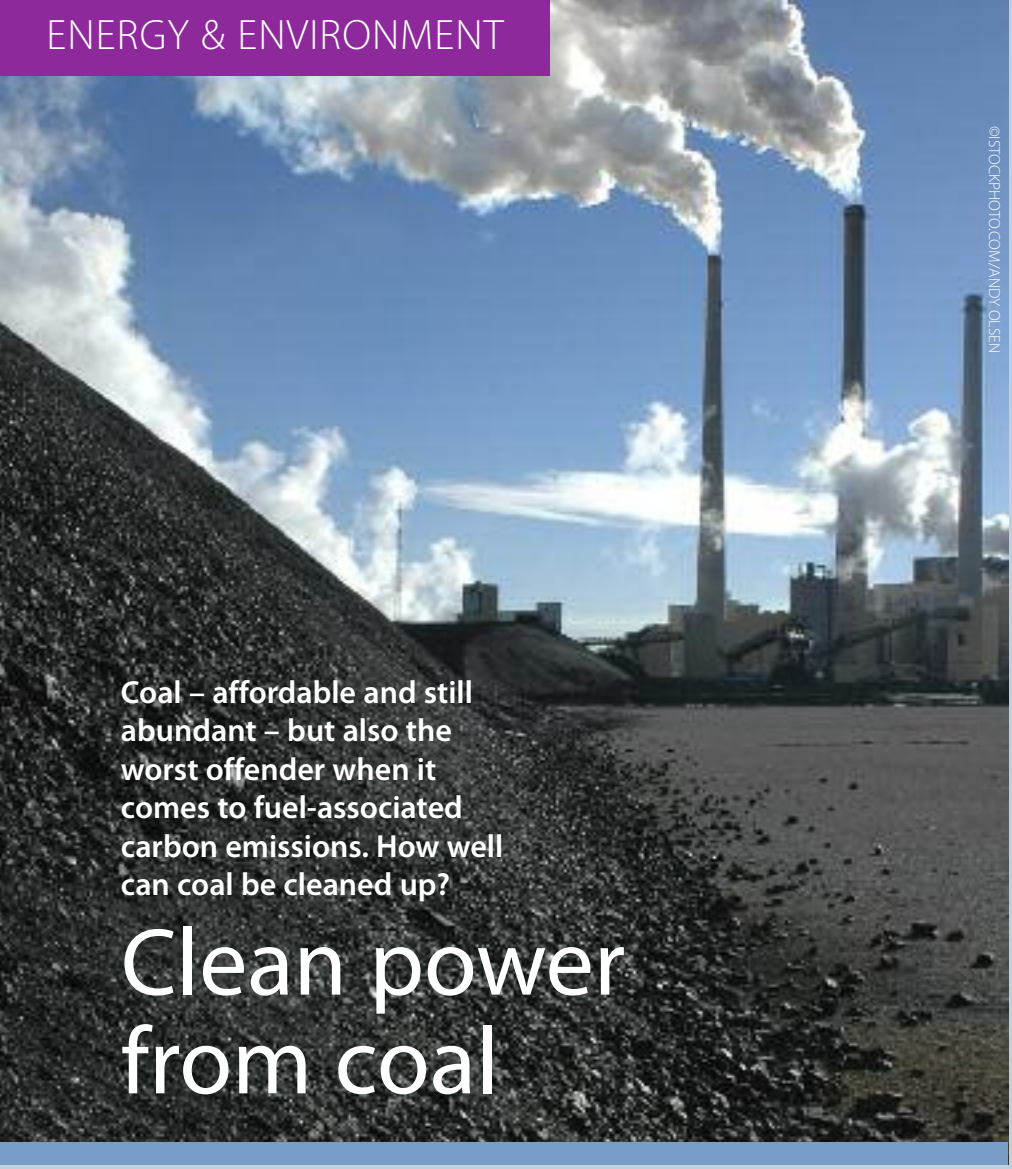
Currently, we have an electricity system in which supply is largely driven by demand. At the household level, most homes have a 'dumb' electricity meter that records cumulative consumption to date. Individuals have very poor information about their instantaneous electricity consumption, and hence may be consuming more energy than they need. It also means that individual electricity demands are unable to respond to the situation of the electricity system as a whole. A 'smart' electricity meter would address both of these problems and be an essential part of delivering an electricity system based on the concept of energy services rather than consumption.

The EPRG study is providing a comprehensive framework for assessing the costs and benefits of smart meters. Data from Ontario and California show that the introduction of smart metering can have two immediate impacts on the electricity system. It might reduce electricity consumption by 5–7% simply by giving people real-time information on their electricity use. It can also allow for the variation of electricity prices across the day to better reflect the costliness of the generation required at that time. Such real-time pricing can result in shifts in peak energy consumption of 8–13% of total electricity demand.

However, these two effects are only the start of the possibilities that smart meters offer. Smart meters are central to the use of information technology to seamlessly manage household energy consumption and production. A smart meter can also ensure that any electricity produced by the household (via micro-combined heat and power or solar panels) can be sold to the grid at a price that reflects its real-time value.

### FlexNet

Smart metering research is part of the work that the EPRG has been carrying out for the past three years in collaboration with a consortium of nine universities under the FlexNet project. Funded by £7 million from the Economic and Physical Sciences Research Council (EPSRC), the project as a whole is looking at the evolution of the UK electricity system to 2050. The research on smart metering has been submitted to the UK Government to assist in its assessment of the best way to roll out smart meters.





**Coal – affordable and still abundant – but also the worst offender when it comes to fuel-associated carbon emissions. How well can coal be cleaned up?**

# Clean power from coal

Coal generates the largest share of the world's electricity and remains the most plentiful of all the fossil fuels. Figures released by the World Energy Council have estimated that reserves of economically recoverable coal are sufficient to last for another 150 years. Its abundance and low cost have ensured coal's place as a mainstay of energy generation worldwide and especially in developing countries. However, burning coal produces more of the greenhouse gas $CO_2$ than most other fossil fuels per unit of energy generated. How can our need for coal be balanced with a move towards a carbon-constrained future?

With funding from the Engineering and Physical Sciences Research Council (EPSRC), chemical engineer Dr John Dennis has teamed up with engineer Dr Stuart Scott to create a coal combustion process that not only maximises energy output but also captures pure $CO_2$, which can then be sequestered in the Earth.

## Clean coal technology

Coal power stations usually burn highly pulverised fuel, turning the hydrocarbons to $CO_2$ and water (as steam, which drives turbines to generate electricity). Because the coal burns in air, which contains a large amount of nitrogen, the resulting $CO_2$ is impossible to sequester without being purified first. Not only is this costly, but a coal-fired station might use as much as a third of its energy output just to run a carbon-capture plant.

The EPSRC-funded study has gone back to the drawing board to find a more effective way of removing $CO_2$, focusing on improving the efficiency of a process for coal combustion known as chemical looping combustion (CLC). In conventional CLC, the fuel is first oxidised in a fuel reactor by a solid metal oxide (the oxygen carrier) in the absence of air, creating steam and pure $CO_2$. When the steam is condensed, what's left is almost pure $CO_2$ plus the reduced metal. The metal is then regenerated into metal oxide in an oxygen reactor, generating substantial quantities of heat for power generation, and is recycled to begin a new cycle of reduction and oxidation.

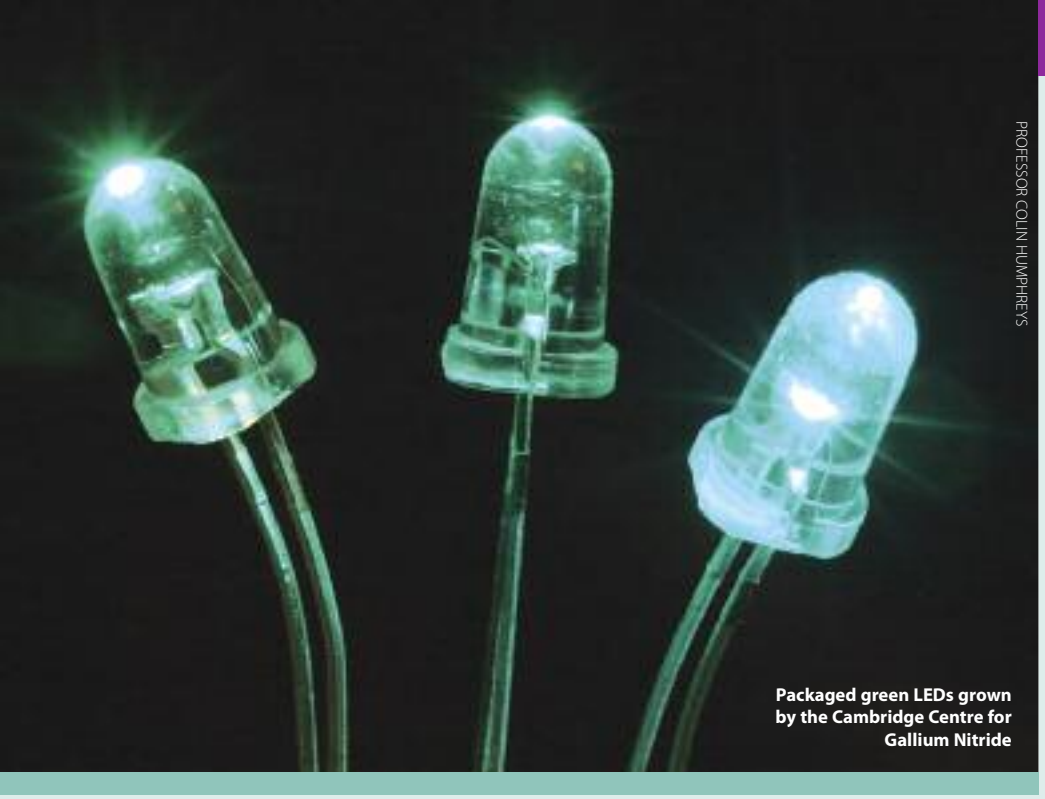
However, using solid fuels in CLC is difficult because the particles of fuel and oxygen carrier cannot be easily separated. Drs Dennis and Scott are developing a technique that overcomes this by gasifying the fuel first (essentially turning coal into hydrogen and carbon monoxide). In the first phase of the cycle, solid fuel is fed continuously into a bed of oxygen carrier, through which is passed steam or $CO_2$, or both: this gasifies the fuel, which reacts in turn with the carrier to form $CO_2$ and steam. When the carrier becomes depleted towards the end of the first phase, the feed of coal is stopped and the inventory of carbon in the bed is allowed to gasify and combust until it is sufficiently small. In the second phase, air is passed through the bed, instead of steam or $CO_2$, regenerating the depleted oxygen carrier. A new cycle then starts.

In a further modification of the process, the researchers have found that they can also isolate hydrogen by regenerating the oxygen carrier in the presence of steam. The resulting hydrogen is clean enough to be used in a fuel cell; the process also has the desirable outcome of exporting heat energy in addition to the hydrogen energy, and also produces pure $CO_2$ that could be sequestered. Work is ongoing to develop synthetic calcium-based sorbents to capture the $CO_2$ for sequestration.

The UK Government's White Paper 'Our Energy Future' recognised the important part that coal-fired generation plays in widening the diversity of the energy mix 'provided ways can be found materially to reduce its carbon emissions'. The hope is that techniques such as those being developed in Cambridge will facilitate cleaner and more efficient coal power generation in the future.

**Dr John Dennis (left) and Dr Stuart Scott**

**For more information, please contact Dr John Dennis (jsd3@cam.ac.uk) at the Department of Chemical Engineering and Biotechnology, and Dr Stuart Scott (sas37@eng.cam.ac.uk) at the Department of Engineering.**



PROFESSOR COLIN HUMPHREYS

**Packaged green LEDs grown by the Cambridge Centre for Gallium Nitride**

# Lighting for the 21st century

**A remarkable light-emitting material, gallium nitride, could slash electricity consumption, purify water and kill superbugs.**

A revolution in lighting is under way. Thanks to advances in the technology, efficiency and cost of light-emitting diodes (LEDs), these devices are ready to take over in the very near future from conventional forms of incandescent lighting. The potential energy savings are huge: statistics from the US Department of Energy estimate that, by 2025, solid-state lighting such as LEDs could reduce the global amount of electricity used for lighting by 50% and, in the US alone, could eliminate 258 million metric tons of carbon emission, alleviate the need for 133 new power stations, and result in cumulative financial savings of over a hundred billion dollars. At the forefront of research underpinning this new lighting paradigm is a focus on the semiconductor gallium nitride (GaN) at the Cambridge Centre for Gallium Nitride in the Department of Materials Science and Metallurgy.

## Why use GaN for LEDs?

LEDs based on GaN, which emits brilliant light when electricity is passed through it, are extremely energy efficient and long lasting. Traditional incandescent light bulbs are only 5% efficient at converting the electricity they consume into light, and, although low-energy light bulbs are 20% efficient, they contain hazardous mercury. Compare this with white GaN LEDs, which are already 30% efficient and have a target efficiency of 60%. GaN LEDs are also incredibly long lasting: an LED can burn for 100,000 hours. In practical terms, this means it only needs replacing after 60 years of typical household use.

In the UK, lighting consumes over a fifth of all the electricity generated at power stations, and GaN LEDs have the potential to reduce this figure by at least 50% and possibly by 75%.

The Holy Grail for GaN is home and office lighting. Research directed at reducing manufacturing costs and improving the quality of light is bringing this goal closer.

## Materials and devices

Research at the Cambridge Centre for Gallium Nitride, directed by Professor Colin Humphreys, the Director of Research in the Department of Materials Science and Metallurgy, stretches from fundamental materials studies through to applications and devices.

The Centre has world-class GaN growth and characterisation facilities and has recently developed an innovative technique for growing GaN on large silicon wafers, instead of the more expensive sapphire wafers; this could deliver a tenfold reduction in LED manufacturing costs. The Centre is also working on improving the quality of light by coating blue LEDs with phosphors to produce white light. This will be improved still further through the use of novel phosphors produced by Professor Tony Cheetham in the Department of Materials Science and Metallurgy.

## The future

GaN LEDs have hit the market rapidly and are already widely used in flashlights and front bicycle lights, as backlighting for mobile phones and interior lighting in cars and aeroplanes, and even to light up landmarks such as the façade of Buckingham Palace and the length of the Severn Bridge. Looking ahead, the timescale for the widespread adoption of GaN LEDs in homes and offices is probably as short as 5–10 years.

Other applications also look promising. Research at the Centre is investigating the possibility of using GaN LEDs to mimic sunlight, which could have important benefits for sufferers of seasonal affective disorder (SAD). And other studies are investigating how UV LEDs, created by adding aluminium to GaN, could be used for killing bacteria and stopping viruses from reproducing, either to purify water in the developing world or to 'sweep' hospital wards to eradicate superbugs.

**Professor Colin Humphreys**

**For more information, please contact the author Professor Colin Humphreys (colin.humphreys@msm.cam.ac.uk) at the Cambridge Centre for Gallium Nitride (www.msm.cam.ac.uk/GaN/). The Centre's research is funded by the Engineering and Physical Sciences Research Council (EPSRC), the Technology Strategy Board (TSB), Aixtron Ltd, Sharp Electronics Europe, QinetiQ, Forge Europa, Philips, Imago Scientific Instruments and RFMD (UK) Ltd, and is performed in collaboration with the University of Manchester and Sheffield Hallam University.**

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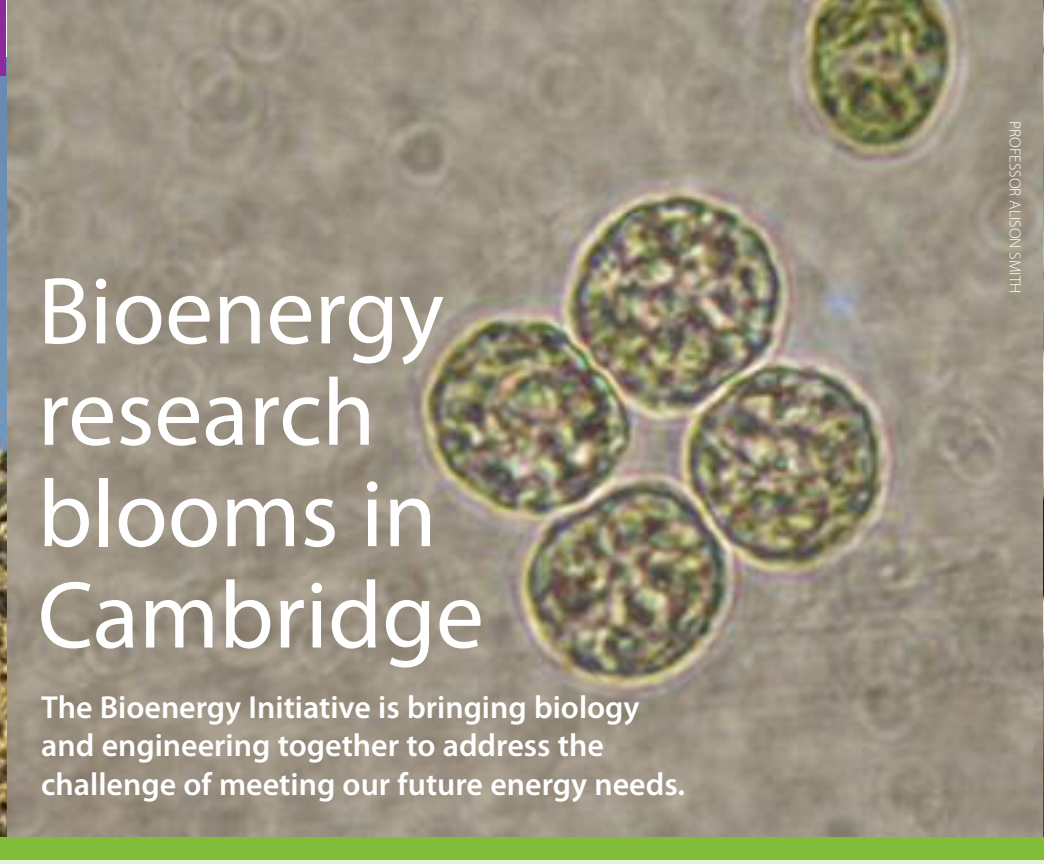

PROFESSOR ALISON SMITH

# Bioenergy research blooms in Cambridge

**The Bioenergy Initiative is bringing biology and engineering together to address the challenge of meeting our future energy needs.**

Plants are the most important natural resource on the planet. Not only do they provide all the food we eat, either directly or indirectly as animal feed, but they are also an important source of building materials and biopolymers, such as rubber, as well as many important pharmaceutical products.

Now plants are increasingly being exploited as a source of renewable energy. Plants harness solar radiation by photosynthesis; because this fixes atmospheric $CO_2$ to produce biomass, using plants as a source of energy is potentially carbon neutral. In addition, compared with other sources of renewable energy, biofuels also offer the major advantage of providing a source of liquid fuel, which is required for transport.

But biofuels have also come under criticism. So-called first-generation biofuels are produced by fermentation of starch from crops such as maize to yield ethanol, or are derived from plant oils yielding biodiesel. Although the amounts produced are small (approximately 3% of European transport fuel energy consumption comes from first-generation biofuels), the use of food crops as a source of raw materials at a time when populations are increasing in size has led to a 'food versus fuel' debate.

Sources of alternative biofuel feedstock that don't compete with food production are needed. Within the past two years, scientists from several Cambridge departments have come together to form the Bioenergy Initiative to explore the potential of next-generation biofuels. These interdisciplinary collaborations are tackling the technical and environmental obstacles that must be addressed to make next-generation biofuels commercially viable. The research is focusing on two main areas: developing fuels based on non-food crops and the parts of food crops that are normally discarded as waste, and developing ways of harvesting energy from algae.

## Plants for bioenergy

Plant material such as wood and straw has the potential to be part of the low carbon solution to replace our fossil-fuel-based liquid transport fuels, provided an environmentally, socially and economically sustainable production method is found. Plants store most of the carbon they take from the atmosphere in their cell walls as polysaccharides. Instead of burning plants to release energy, the plant biomass could be more usefully converted to liquid fuels such as ethanol by chemically releasing these sugars, and then using microbes to ferment them to fuels. This requires that as much as possible of the cell wall polysaccharides are used, with minimal expenditure of energy and minimal use of expensive chemical and enzymatic treatment to extract them. Much research is needed to make this an industrial reality.

Early in 2009, the UK Biotechnology and Biological Sciences Research Council (BBSRC) announced a £27 million investment in research in this area. The new virtual **BBSRC Sustainable Bioenergy Centre** (BSBEC, www.bsbec.bbsrc.ac.uk/) is a partnership of six research hubs and industry. As part of this, Dr Paul Dupree in the Department of Biochemistry leads the BSBEC Cell Wall Sugars Programme in Cambridge. The Programme aims to improve the energy conversion process by understanding how sugars are locked into the plant biomass.

Up to 10 million tonnes of wheat straw could be available in the UK each year for energy production. If converted to ethanol, this could generate a few percent of UK transport fuel requirements. Increases beyond this are possible if crops such as willow or *Miscanthus* grass are grown on land that is unsuitable for food crops. Cambridge BSBEC researchers are contributing to studies on the farming of these crops at Rothamsted Research, Hertfordshire, to improve yields and to understand how to optimise sustainability of the crops in terms of energy input and biodiversity.

By analysing how sugars are locked into plant cell walls, research in the Dupree group aims to identify the best plants and the right enzymes to release the maximum amount of sugars for conversion to biofuels. The research team is building links with industry and other research centres to ensure their findings will increase the sustainable use of plants for fuels and other renewable products.

## Pond slime to the rescue

The other major strand of research being undertaken in the Initiative has focused on algae. These simple aquatic plants are responsible for an estimated 50% of global carbon fixation and offer


Sources of next-generation biofuel



considerable advantages compared with biofuels from land crops. Many species are able to produce high levels of hydrocarbons, and they can also divert photosynthetic energy into another ready-to-use fuel, hydrogen. Algal productivity can be much higher than that of land plants per unit area, because of their fast growth rates, and they can be grown on marginal land, or even offshore, where they don't compete with food crops.

However, there is little or no infrastructure for the cultivation and harvesting of microalgae on a large scale, apart from commercial operations employed for the production of high-value products such as the food supplement astaxanthin, which is used in the fish industry. Moreover, for fuel production, cost margins are critical, and most importantly the energy that is obtained from the fuel extracted must be greater than that used in the process. To address some of the many difficulties that will be encountered in attempts to commercialise biofuel production from algae, the **Algal Bioenergy Consortium** (ABC, www.bioenergy.cam.ac.uk/abc.html) was founded in 2007 by Professor Alison Smith (Department of Plant Sciences), together with Professor Chris Howe (Biochemistry), Dr John Dennis (Chemical Engineering and Biotechnology) and Dr Stuart Scott (Engineering).

A major issue is which algal species to grow. Although most people are familiar with the two broad categories of algae – seaweed on the beach or the scum that grows on ponds or on the patio – the algal kingdom is incredibly diverse. However, our knowledge of algal biology in general is poor, and we know even less about how these organisms would behave in the large-scale dense cultures that would be needed for biofuel feedstock production.

The research focus of the ABC is to study a few species in depth, taking advantage of molecular tools that are being developed for some model species. Through studying ways in which algae make fuel molecules and how the algal cell wall is built, the researchers aim to discover ways to increase the extraction of fuel molecules with maximum yields.

Together with Dr Adrian Fisher in the Department of Chemical Engineering and Biotechnology, the ABC is also investigating ways of harvesting hydrogen as an energy source in a biophotovoltaic device. The method is based on 'stealing' electrons from the photosynthetic process. Although currents so far are low, with funding from the Engineering and Physical Sciences Research Council (EPSRC) and the formation of a University spin-out, H+ Energy, the combination of biological and engineering approaches is helping to optimise the prototypes.

## Part of the energy spectrum

At the present time, an estimated 1 million years' worth of fossil fuel deposition is consumed each year. As fossil fuels become scarcer and more expensive to extract, and carbon emissions increase as a result of their use, renewable sources of energy will be essential. Given the size of the challenge to provide energy security in a sustainable way, it is important to explore the entire spectrum of possible energy sources. Biofuels from plants and algae have the potential to offer both a sustainable and carbon-neutral supply, but many hurdles need to be overcome before this potential is realised. With the critical mass of bioenergy researchers now working in Cambridge, the Bioenergy Initiative has the opportunity to play a major role in tackling these issues.

**Professor Alison Smith and Dr Paul Dupree**

**For more information, please contact the authors Professor Alison Smith (as25@cam.ac.uk) at the Department of Plant Sciences and Dr Paul Dupree (pd101@cam.ac.uk) at the Department of Biochemistry, or visit www.bioenergy.cam.ac.uk/**

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# Material efficiency

**A consortium led by Dr Julian Allwood aims to drive a step-change in the manufacturing of steel and aluminium to meet 2050 carbon targets.**

**One way to save energy in steel manufacturing is to reduce the number of heating and cooling stages required**

It is widely agreed that a cut of at least 60% in global greenhouse gas emissions will be required by 2050 to limit the adverse effects of climate change. Emissions from industry are dominated by those arising through the manufacture of five key materials: cement, steel, plastic, paper and aluminum. Steel and aluminium are responsible for 8% of global energy-related emissions, and demand for these metals is forecast to double by 2050. Industry efforts to date have focused on reducing energy in primary production, as well as recycling metal by melting and re-casting. However, recycling rates are already around 60–70% and the most optimistic projections for energy efficiency improvements deliver only 30% reduction per unit output of material. How, then, can the 2050 targets be achieved?

Dr Julian Allwood, Senior Lecturer in the Department of Engineering, has been awarded a five-year, £1.5 million Engineering and Physical Sciences Research Council (EPSRC) Leadership Fellowship that aims to help industry meet this challenge. He proposes that a key element of a low carbon metals economy will come from applying material efficiency strategies in which future production of new primary metal is reduced, for instance by reusing metals without melting them or by extending their service life. The funding for the project, WellMet2050, supports a team of seven and is supported by a large industrial consortium.

'Working with academic partners in several countries, future scenarios of metal flows and associated economic forecasts will be developed to anticipate what must be achieved,' explained Dr Allwood. 'These will be explored with a consortium of 20 major global companies spanning the metals supply chain, to identify the barriers to achieving them and to find technical, economic and policy measures required to overcome these barriers.' In total, the companies have committed £2 million of in-kind funding.

## Collaborating with companies

Analysing examples of material efficiency strategies will form an important component of the research. For instance, in India, up to a sixth of the country's supply of steel is provided by labour-intensive ship breaking, supplying plates of used steel that are re-rolled rather than melted. Can oil companies such as BP, faced with finding economically and environmentally sound ways of decommissioning end-of-life oil rigs, learn valuable lessons from this approach? Can such lessons also apply to the reuse of steel girders from old buildings? The average life of a commercial building is 30–60 years before demolition, but the buildings are rarely 'broken', just no longer 'fit for purpose'. Can buildings that are constructed on a strong and open frame be re-configured? Research with industrial partner Arup will explore the carbon emissions savings that could be achieved through extending building life.

The research will also include work with Corus, Novelis and Alcoa to see if designing ways of better thermal management could reduce the number of heating and cooling stages required in metals production.

## Creating change in industry

The research will be split between two themes: a business analysis theme will identify future scenarios, barriers and a roadmap for meeting the target. This work will include specific analysis of future metal flows, application of a global economic model and the analysis of policy measures. A technology innovation theme aims to optimise the requirements for metal use through novel manufacturing process design, to increase material and energy efficiency in forming and finishing, and to develop solid-state closed-loop recycling for metals. Together, this basic research has the potential to drive a step-change in material efficiency, by demonstrating that a different flow of metal through the global economy is technically and economically possible, and by inspiring and informing those who can influence change.

Dr Julian Allwood

**For more information, please contact Dr Julian Allwood (jma42@eng.cam.ac.uk) at the Department of Engineering or visit www.wellmet2050.com/**

# Cambridge Centre for Energy Studies

**The future of the global energy network is the driving force for the research programme at Cambridge Centre for Energy Studies.**

The future of energy is high on the global political agenda and presents rich opportunities for innovative, interdisciplinary research. Cambridge Centre for Energy Studies (CCES), established in 2007 and based at Judge Business School, provides a platform for new energy-related research and discussion, investigating the future of the global energy system, the barriers to energy security, and the policies and interventions required to overcome them.

CCES comprises a multidisciplinary team of researchers and project coordinators, linking researchers in the fields of management, engineering, architecture, physics, economics, applied maths and geography to a wider network of specialists in government and businesses around the world. With core support from BP, ExxonMobil, Grosvenor and Deloitte, CCES is developing a diverse research framework, bringing in key specialists and advisors for individual projects to give a range of perspectives on challenges to the future of global energy security. CCES also funds the Arctic Geopolitics Programme based at Cambridge's Scott Polar Research Institute.

## A broad research portfolio

Research projects under way at CCES fall within three major work programmes – the efficiency of energy use, the geopolitics of energy, and the information management and governance of environmental change. Examples of the broad research portfolio at CCES include:

**Energy efficiency in the built environment**: Existing buildings are responsible for over 40% of the world's total primary energy consumption, and account for 24% of world $CO_2$ emissions. Increasing energy efficiency in cities is therefore a crucial step in delivering reductions in energy consumption. CCES is exploring the demand side of energy management in the built environment, investigating possible interventions for addressing the economic, regulatory, technological and behavioural challenges to increasing energy efficiency.

Through case studies in the UK and around the world, in existing and new residential and commercial properties, CCES is preparing a series of scenario analyses and research papers for release during the next three years. The project has the support of property management firm Grosvenor and participation by research partners, including other universities, local government, regional development agencies and specialist consultancy firms with expertise in the future of the built environment. CCES is also involved in the Energy Efficient Cities initiative (see page 8). (Principal Investigator: Dr Theo Hacking, th252@cam.ac.uk).

**National oil companies (NOCs)**: NOCs control approximately 71% of proven global reserves and their share of world oil production is predicted to rise from 57% in 2007 to 62% by 2030. Unlike international oil companies, NOCs must balance the needs of their consumer base, their shareholder governments and their citizens as the ultimate beneficiaries of national petroleum wealth.

CCES is identifying and categorising the challenges that will influence the performance and decisions of NOCs over the next decade, such as how to manage political relationships both domestically and abroad, how to integrate new technologies, how to manage human resources, and the role of NOCs in responding to environmental change. Challenges to NOC business models from external forces need to be investigated to understand how NOCs will improve their efficiency and performance, develop cleaner energy production, and ultimately deliver greater shareholder value. (Principal Investigator: Dr Othman Cole, oc219@cam.ac.uk).

**Global Water Initiative**: As part of the University of Cambridge's collaboration with the University of California San Diego, supported by the Moore Foundation, CCES is contributing to an international research network to investigate the impact of climate change and climate variability on water resources in vulnerable regions. CCES is convening experts from around the world to examine the connections between changing water supply and climate variability in order to develop integrated approaches to managing natural resources, and to support the expansion of regional research capacity and adaptation to changing water availability. Working with Professor Lord Julian Hunt, CCES is conducting field research and analysis, and in September 2009 will be hosting an international symposium on the impacts of climate change in Africa.

**CCES welcomes opportunities that contribute to the wealth of energy research at the University of Cambridge. For more information, please contact Sally Daultrey (sd314@cam.ac.uk), Acting Development Manager at Cambridge Centre for Energy Studies (www.futureofenergy.org.uk/).**

DEAN AND CHAPTER, WESTMINSTER ABBEY

**Through his exploration of the science of art, the recipes of medieval artists and the writings of alchemists, art conservation scientist Spike Bucklow sets out to disentangle the alchemy of medieval paint.**

**The feeding of the five thousand; detail from the Westminster Retable**

# Dragonsblood: the alchemy of paint

Dragonsblood – a red pigment prized for the best part of two millennia and discussed by apothecaries, alchemists and painters alike – was said to be the mixed, coagulated blood of dragons and elephants collected from the place where the beasts fought and died together. Actually, it was a tree resin, and a sample of the pigment can be found today in Queens' College, in a medicine cabinet assembled in 1702 by Giovanni Francesco Vigani, the University of Cambridge's first Professor of Chemistry. Dragonsblood also features in *The Alchemy of Paint,* a book about the colours used by medieval artists. It is a book that attempts to understand medieval artists' materials as they were perceived by the people who used them. But it was inspired by a very practical modern problem.

## Conserving the lost Retable

I work as a scientist in the University's Hamilton Kerr Institute, a department of The Fitzwilliam Museum that specialises in the conservation and restoration of paintings. In 1994, the Institute received the Thornham Parva Retable, a 12ft-long altarpiece painted in the 14th century for a Dominican Priory in Thetford, Norfolk, by artists from Norwich. It had survived destruction in Henry VIII's dissolution of the monasteries in the 16th century but was lost until 1927, when it was discovered in a stable loft. By this time, the original 1330s paint was almost entirely covered with paint applied in the 1770s, which had to be removed in order to conserve the medieval material.

The Institute's treatment of the Retable was the focus of considerable scrutiny because it is the largest, best-preserved and second oldest altarpiece in the UK. A 22-strong committee of academics, funding bodies and parishioners discussed how to proceed. Over the course of two years, during which microscopic paint samples were analysed by electron microscopy, gas chromatography and mass spectrometry, a consensus gradually came together and the conservation work began.

## Cultural contexts, recipes and alchemists

The suggested treatment strategy was accepted, in large part, because it was based on scientific evidence. As a conservation scientist, from these analyses I understood the consequence of the artists' materials in terms of their physical and chemical properties, their interaction with the environment and their behaviour when undergoing conservation treatment. But I began to wonder about the medieval artists themselves: how would they have explained the materials and methods involved in making an altarpiece? Were they influenced by their Dominican patrons or indeed by the closeness of Cambridge's intellectual orbit, both well known in the 14th century for their interest in science?

Looking for clues, I consulted artists' treatises detailing medieval recipes for pigments and paints, such as the manuals written by Theophilus Presbyter, a

12th-century Benedictine monk, and Theodore Turquet de Mayerne, physician to Charles I and friend of the artist van Dyck. But connecting the physical evidence offered by paintings to the artists' recipes, which often verged on the bizarre and magical, was not always straightforward. The legendary origin of dragonsblood is a case in point. Why would artists say that this derived from dragons and elephants fighting to the death when they knew dragonsblood was really a tree resin? Other medieval recipes were just as evocative: a stone from the doorstep of Paradise and a metal won by one-eyed horsemen from ferocious griffins near the North Pole. The recipe books certainly didn't make sense according to the science that I knew. I needed to brush up on the science with which the artists were familiar: alchemy.

## Cloak-and-dagger

The medieval palette owed much to what some have described as 'cloak-and-dagger science', conducted by artists employing secret recipes to create the luxurious colours we are familiar with today. This was the era of alchemy, best known for the quest of alchemists to turn base metals into gold and to find the elixir of eternal life, when scientists like the Dominican Albertus Magnus wrote on the subject. Researching their writings provided me with the necessary technical background to begin the challenge of connecting the physical evidence offered by the scientific analysis of paintings and the recipes in artists' treatises. *The Alchemy of Paint* is the fruit of that challenge.

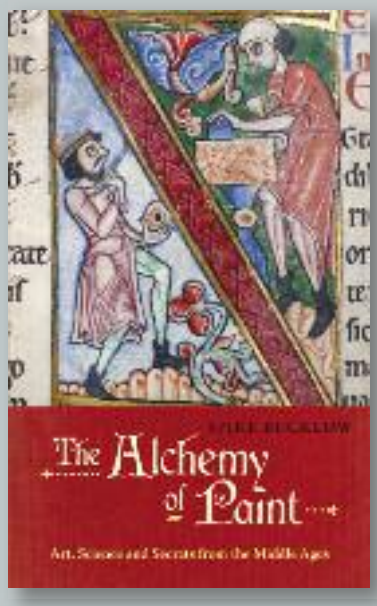
Colours, it seems, were read differently in the mindset of medieval Europe. Not only in how people responded to them – 'scarlet' today describes a colour, but it was originally a type of cloth – but also in how artists considered their materials. Their ideas, fed by the philosophers and scientists of the time, would probably not be too out of place in the University's 1209 syllabus 800 years ago. Today, an awareness of their ideas helps ensure that conservation of art is undertaken with cultural sensitivity and also immeasurably enhances our appreciation of their art.

## Walking the dog

Attempting to join up artists' theory and practice has been a lot of fun. Walking my dog around Cambridgeshire, across fields and over the nearest things to hills that the region has to offer, I saw the sun set and the stars come out, the seasons come and go, and the colours change. I attempted to familiarise myself with what CS Lewis called *The Discarded Image*, the poetic way that the medieval world view synthesised 'the whole organisation of their theology, science and history into a single, complex, harmonious mental model of the universe'. In the medieval world, everything had meaning, even the pigments they painted with. Guidance from the 'discarded image' helped me to consider artists' materials and methods in ways that modern science could not.

*The Alchemy of Paint* was a response to a very practical situation: the desire for a broader and deeper view of the Thornham Parva Retable, as well as the Westminster Retable, treated between 1998 and 2005 at the Institute, and the Macclesfield Psalter acquired by The Fitzwilliam Museum in 2005. I was lucky enough to be by the bus-stop, as it were, when three medieval masterpieces came along together. It was an enormous privilege to get to know them and they all informed the thinking behind *The Alchemy of Paint*. And I certainly hope that the book will have a practical effect – to encourage students and researchers to engage more profoundly with the products of other cultures.

And the Thornham Parva Retable? It finally returned home in 2003, its treatment hailed as a great success by parishioners, funding bodies and the academic community alike. It even won an award.




***The Alchemy of Paint: Art, Science and Secrets from the Middle Ages* by Dr Spike Bucklow is published by Marion Boyars Publishers**

**Dr Spike Bucklow**

**For more information, please contact the author Dr Spike Bucklow at the Hamilton Kerr Institute (www-hki.fitzwilliam.cam.ac.uk/).**

# Zero-carbon houses

## A consultancy project with grand designs is informing the structure of energy-efficient homes of the future.

MICHAEL RAMAGE

Tile vaulting gives the house strength and thermal mass

Over 600 years ago Spanish builders knew how to design a house that would retain the natural heat of the winter sun and be cool in the summer. The techniques they built with, called tile vaulting, are being revived by Michael Ramage of the University's Department of Architecture in a state-of the-art building that could be a prototype for cheaper energy-efficient homes.

The house, which was featured on Channel 4 Television's *Grand Designs*, was designed by architect Richard Hawkes, with consultation on structural design by Michael Ramage and Philip Cooper, who is a Visiting Lecturer at the Department of Architecture and the Technical Director of Scott Wilson Engineers.

'The inspiration to use the Spanish design came from my research into contemporary applications of historic construction methods,' explained Ramage. The vaulting gives the house structural strength and obviates the need for embodied energy-intensive materials such as reinforced concrete. It also provides it with great thermal mass, enabling the building to retain heat and absorb fluctuations in temperature, reducing the need for central heating or cooling systems.

The roof, which is overlaid with gravel and soil, holds solar panels that generate 3,600 kwh of energy a year. Rather than buying electricity, the excess is sold to the National Grid. The heat from the solar panels is captured in a unique storage system in which a specially developed salt solution changes from solid to liquid in order to conserve heat. Ramage and Dr Allan McRobie (Department of Engineering) are monitoring the performance of the energy system to develop better ways to reduce demand.

The Consultancy Services of Cambridge Enterprise Limited set up and managed the contracts with Michael Ramage and with Scott Wilson Limited, acting as an intermediary party. This arrangement provides the academic with reduced personal risk and the ability to use the University's name and facilities, which they are unable to do if acting in a personal capacity. Cambridge Enterprise enters into over 100 contracts annually with public and private sector organisations worldwide who wish to use the services of University of Cambridge academics.

**For more information about this research, please contact Michael Ramage (mhr29@cam.ac.uk). For more information about Cambridge Enterprise Consultancy Services, please contact Dr Paul Seabright, Head of Consultancy Services (paul.seabright@enterprise.cam.ac.uk; www.enterprise.cam.ac.uk/).**

# Increasing value generation from product-related services

## Cambridge will lead a consortium of universities awarded £2.2 million as part of an initiative to take an integrated approach to knowledge transfer.

The Engineering and Physical Sciences Research Council (EPSRC) last year launched a multimillion pound scheme to help universities ensure that their academics' discoveries are turned into tangible economic and societal benefits for the UK. As part of this initiative, a collaboration of the Universities of Cambridge, Bath, Cranfield, Exeter and Nottingham has been awarded £2.2 million through a Collaborative Knowledge Transfer Award (KTA) to commence on 1 October 2009 and last for three years.

The partner universities are all members of the Support Service Solutions: Strategy and Transition (S4T) consortium, a research programme led by Cambridge's Institute for Manufacturing and jointly funded by EPSRC and BAE Systems. The programme is developing and applying service science to increase value generation in sectors where products and services are combined, such as aerospace, power generation, pharmaceuticals and chemical engineering.

The KTA will help to ensure that EPSRC-funded research in Cambridge and the other partner universities is fully exploited, helping to create an environment in which knowledge transfer is valued and encouraged just as much as is the generation of original results.

Professor Duncan McFarlane, S4T Principal Investigator, explained: 'The KTA aims to bridge the knowledge transfer gap between research into complex engineering services and its practical application. This will ensure that a greater proportion of

BAE SYSTEMS

the value created remains within the UK.' Dr Chris Pearson, S4T Programme Coordinator, added: 'This funding will allow us to develop ways in which new knowledge is turned into practical tools and innovative techniques that will provide long-term benefits.'

**For more information, please contact Dr Chris Pearson (cp349@cam.ac.uk) at the Institute for Manufacturing.**

# Electronic Laboratory Notebooks for academic research

## A pioneering commercial and R&D relationship between the Department of Chemistry and a leading provider of scientific software solutions brings research E-notebooks to Cambridge.

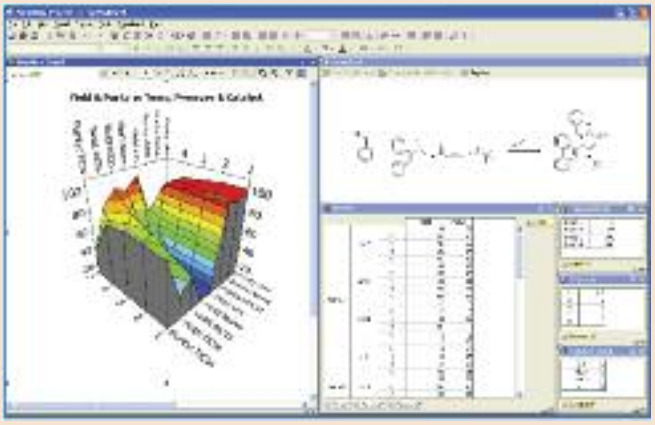
The ways in which we store and access data are constantly improving, and one of the latest technologies to reach the academic environment is the Electronic Laboratory Notebook (ELN). Already well known in the pharmaceutical industry, ELNs hold great promise as tools to enhance research excellence by improving the capture, storage, searchability and sharing of experimental data.

ELNs for academic research are moving a step closer thanks to a new relationship between the Department of Chemistry and IDBS, a leading supplier of research data management to international R&D organisations. IDBS has been chosen to supply the Department with its award-winning laboratory notebook (E-Workbook) and will also enter a collaborative R&D initiative in research informatics.

Through the implementation of E-Workbook, which is already in use within commercial life sciences, engineering, manufacturing, energy and food technology organisations, IDBS will gain valuable knowledge as to how its existing functionality can be expanded to benefit the broad spectrum of academic chemical research carried out within the Department. And the Department in turn will use the system as a collaborative platform for many of its ongoing national and international academic research programmes.

The collaborative aspect of this relationship provides both organisations with significant cheminformatics assets and opportunities for future technology development.

'Working as both a supplier and research collaborator with the Department of Chemistry is an exciting prospect for IDBS. We are confident that our existing capabilities will support the diverse research and data-sharing requirements of the



IDBS

**Electronic Laboratory Notebooks will provide an environment that helps chemists optimise workflow and manage data**

Department. Working with some of the most advanced minds in the development of new chemical informatics technologies will allow innovative products to be brought to the market,' said Neil Kipling, founder and CEO of IDBS.

Professor Robert Glen, from the Department of Chemistry, added: 'We see this as an exciting opportunity to capture, analyse and investigate our data at a deeper level, enabling easy access and interrogation of results, and making research much more effective and faster. There is a great opportunity to research how we can expand functionality to all of chemistry – a big task but something that is a very worthwhile goal.'

**For more information, please contact Professor Robert Glen (rcg28@cam.ac.uk) or visit www.idbs.com/**

# Polymer interconnects

## The Department of Engineering and Dow Corning are working together to develop low-cost optical interconnects for high-speed data communications.

Over the past five years, the Photonics Systems Group in the Engineering Department has collaborated with Dow Corning through their participation in the Centre for Advanced Photonics and Electronics (CAPE) and the Cambridge Integrated Knowledge Centre (CIKC). Led by Professor Ian White and Professor Richard Penty, the project's goal has been to achieve highly manufacturable but very high-speed (>10 gigabits per second) communication systems, such as required between high-end computers.

To accomplish this, the efficiency of high-speed data interconnects on electronic circuit boards must be increased without also increasing manufacturing costs. The material chosen to realise this goal is siloxane, which is capable of withstanding high operating and process temperatures, and yet components can be manufactured under conditions similar to those used to manufacture standard printed circuit boards.

Siloxane materials have been developed by Dow Corning, a global leader in silicon-based technology and innovation. The company wished to see their materials come closer to the marketplace through the realisation of high-performance technology demonstrators, as Dr Terry Clapp from Dow Corning explained: 'Systems proof of the materials and process required a team of exceptional skill and knowledge of the contemporary state of communication technology and we identified that in Professor Ian White's and Professor Richard Penty's activities in CAPE.'

As well as contributing materials expertise, Dow Corning transferred the technology for waveguide processing to the University to allow independent demonstration of device fabrication. The Photonics Systems Group has in turn provided waveguide and device designs, mask layout, and device and systems test.

Commenting on the success of the relationship, Professor Penty said: 'Working with the materials expertise from Dow Corning has allowed us to develop state-of-the-art polymer components and systems in a way we wouldn't have been able to do on our own.' A computer backplane to interconnect multiple computer blade servers has now been built with a total data capacity in the terabit range and a signal loss that is a world-record low.

**For further information, please contact Professor Richard Penty (rvp11@cam.ac.uk).**

# The Cambridge BioResource: facilitating the study of health and disease


**The Cambridge BioResource provides a new approach to understanding why some of us suffer from certain common diseases, while others don't.**

Not everyone reacts in the same way to the challenges of a modern lifestyle. The incidence of common conditions such as heart disease and obesity, and immune-mediated diseases such as allergy, asthma, inflammatory bowel disease and type 1 diabetes, is on the increase. Some 20 million people in the UK are said to be living with some form of chronic disease, which presents a significant cost burden to the UK's economy and healthcare system, and has a major impact on quality of life.

Recent advances have elucidated how genes and their natural variants influence susceptibility to common diseases. But our understanding of the links between disease susceptibility, genetic make-up (genotype), how genes affect the characteristics of individuals (phenotype), and what the impact is of environmental effects such as our lifestyle choices, has lagged behind. One solution to the challenge of identifying gene functions and their altered effects due to common gene variants is to study healthy individuals from the general population.

The Cambridge BioResource, located on the Cambridge Biomedical Campus, has been designed specifically for this purpose. Set up in 2004 as a joint collaboration between the University of Cambridge and the Medical Research Council (MRC) Epidemiology Unit, Cambridge BioResource has taken an innovative and highly efficient approach to facilitating disease-specific studies that are based on studying normal characteristics of healthy individuals.

## One-stop shop

The Cambridge BioResource has established a resource of volunteers (phase 1) from the Cambridge area who are willing to be approached and invited to participate in a wide variety of local medical research studies (phase 2 studies). Through collaboration with the National Health Service Blood and Transplant Centre, Cambridge BioResource now has over 9,000 members on its volunteer panel. Selection for phase 2 studies is based on the volunteer's genotype, determined from DNA isolated from their blood or saliva sample taken as part of their recruitment. Each phase 2 study has its own specific selection criteria that are used by the Cambridge BioResource team to screen the bank and approach those volunteers who match. Volunteers are free to decide whether or not they wish to take part in the ensuing study and are approached a maximum of four times each year.

In this way, the resource provides something of a 'one-stop shop' for any study that requires the analysis of a cohort of individuals selected from a large cross-section of the general population: a researcher studying a specific disease is essentially provided with a bespoke bank of samples that correspond to precisely the

subset of the population they need to study. This allows much more powerful and cost-effective analyses of genotype–phenotype associations by normalising as many features of the analysis as possible. It also does away with the need for each research study to conduct its own costly and time-consuming recruitment of volunteers.

## Facilitating research

The Cambridge BioResource has grown into an invaluable facility that is being utilised by several research groups:

- Professors John Todd, David Clayton and Linda Wicker at the Cambridge Institute for Medical Research are using blood samples to determine the functions of the genes that cause type 1 diabetes (see panel).
- Dr David Savage, Dr Sadaf Farooqi, Professor Steve O'Rahilly, Professor Nick Wareham and Dr Francis Finucane at the Institute of Metabolic Science are aiming to improve our understanding of how genetic variants alter body-weight regulation and diabetes risk.
- Dr Willem Ouwehand at the Department of Haematology is analysing the genes and mechanisms involved in cardiovascular disease.
- Dr Andy Calder at the MRC Cognition and Brain Sciences Unit (CBSU) is using functional magnetic resonance imaging (fMRI) to determine what genetic factors affect the neural coding of emotional signals in the brain.
- Dr Adrian Owen at the MRC CBSU is using fMRI to understand conditions such as Parkinson's disease and obsessive–compulsive disorder.

## Towards 10K and beyond

Funding until March 2012 has recently been secured from the National Institute for Health Research (NIHR) through collaboration with the Cambridge Biomedical Research Centre. This will help increase the panel to over 10,000, as well as assist in the recall of volunteers to further phase 2 scientific research studies. Applications from researchers who would like to use the Cambridge BioResource are open to ethically approved research studies across Cambridge.

**For further information, please contact the Study Coordinator (Tel: +44 (0)1223 763223; Email: bioresource@cimr.cam.ac.uk) or visit www.cambridgebioresource.org.uk/**

## BioResourcing the study of diabetes

Professor John Todd

Type 1 diabetes is one of the most common and serious diseases of children, requiring constant blood glucose monitoring and life-long insulin injections, and its incidence is increasing. In Europe, new cases of diabetes in children under five are expected to double by 2020.

Over the past 10 years, Professors John Todd, David Clayton and Linda Wicker in the Juvenile Diabetes Research Foundation/Wellcome Trust Diabetes and Inflammation Laboratory (DIL) have been hunting for genes in the human genome that are responsible for the strong inheritance of type 1 diabetes in families. They have discovered over 40 regions of the genome that in various combinations give rise to genetic susceptibility or resistance to the disease.

Diabetes is caused by an adverse reaction of the immune system to the pancreatic beta cells that make insulin. Genes known as HLA, which normally recognise infections and initiate immune responses against them, aberrantly recognise insulin and instigate the destruction of the cells that produce it. These anti-self responses are normally held in check by the immune system in a process known as tolerance but, in people at risk of type 1 diabetes, this regulation is not as strong.

DIL researchers are using the Cambridge BioResource to understand how the diabetes genes work in establishing tolerance. The activity of a cell type (T cell) that carries out the destruction of beta cells is modulated by binding to a soluble molecule called interleukin-2 (IL-2). Using the Cambridge BioResource, PhD student Calli Dendrou and Dr Vincent Plagnol in the DIL have discovered that some individuals have variants of the IL-2 receptor gene that alter the expression of IL-2 receptors on T cells. Because this modulates the ability of T cells to respond to IL-2, it presumably also determines whether healthy or dangerous immune responses take place, and therefore may be an inherited phenotype of the development of type 1 diabetes. Importantly, because the volunteers selected through the Cambridge BioResource were selected on the basis of their genotype (i.e. variants of the IL-2 receptor gene) rather than their phenotype (having or not having diabetes), the researchers know the immune characteristics being uncovered are not caused by type 1 diabetes but occur naturally in the general population.

The ongoing research project will continue to use the Cambridge BioResource to investigate the IL-2 pathway, as well as other pathways suggested by new genes that the researchers have mapped across the genome. The long-term goal is to identify disease precursor phenotypes that occur in children before the harmful autoimmune response gathers pace, and to determine whether these precursors are altered by environmental factors that occur early in life. Knowledge of these genotype–phenotype–environment interactions will help in the design and undertaking of future clinical trials to prevent the autoimmune response occurring in the first place, by bolstering the natural regulatory mechanisms of the immune system that in most of us are highly successful at preventing autoimmune disease such as type 1 diabetes.

**For more information, please contact Professor John Todd (john.todd@cimr.cam.ac.uk) at the Cambridge Institute for Medical Research (www.cimr.cam.ac.uk/).**

**How did an Egyptian storeroom come to hold a thousand years' worth of manuscript fragments and why are they one of the greatest literary treasures ever found?**

# Treasures of the genizah

The genizah of the Ben Ezra Synagogue

The single largest and most important collection of medieval Jewish manuscripts in the world, and one of the greatest literary treasures of Cambridge University Library, was recovered from the dusty storeroom, known as a genizah, of an ancient Egyptian synagogue. The fragments, now known as the Taylor-Schechter Genizah Collection, are a treasure-trove of priceless Jewish manuscripts, containing examples of practically every kind of written text produced by the Jewish communities of Cairo, Jerusalem, Damascus and elsewhere over a period of more than 1000 years.

## Bibles and bills

The Collection was discovered by Solomon Schechter, Reader in Talmudic and Rabbinic Literature at Cambridge, in 1896, in a synagogue in Fustat, Old Cairo. Schechter was taken to see the genizah of the 1000-year-old Ben Ezra Synagogue, into which worn-out Jewish books, documents and other writings had continually been placed since the Middle Ages in fulfilment of a rabbinic prohibition against the destruction of sacred texts. Realising the immense scholarly potential of these manuscripts, Schechter obtained the approval of the synagogue authorities to bring them back to Cambridge, where they could be carefully conserved and studied. With financial backing from the Master of St John's College, Charles Taylor, he packed two-thirds of the contents of the genizah into tea-chests and shipped them to England. The Collection was presented to Cambridge University Library in 1898.

Great discoveries followed: the first glimpse of an unknown text that would, following its unearthing among the Dead Sea Scrolls, become known as the Damascus Document; and dozens of manuscripts written in the hand of some of medieval Judaism's greatest figures. But the unique aspect of this archive is that it preserves the spectacular alongside the commonplace: butcher's bills, marriage contracts, private letters and IOUs nestle against invaluable manuscript leaves of the Jerusalem Talmud, rare or unique biblical commentaries and thousands of previously unknown poems by the leading Hebrew poets of Spain and Palestine. The fragments continue to provide a rich research resource today (see opposite page).

## A 21st-century genizah

This spectacular archive has been the subject of intensive work in Cambridge University Library for the past 30 years, since the creation of the Genizah Research Unit in 1974. Reliant upon charitable and research grant funding, the Unit has succeeded in completing the conservation of 193,000 fragments, and continues with an extensive programme of cataloguing, research and public education. Now, thanks to an Arts and Humanities Research Council (AHRC) grant, three Research Associates have begun work describing and digitising 14,000 items from the 'Old Series' of the Collection, containing some of the rarest pieces.

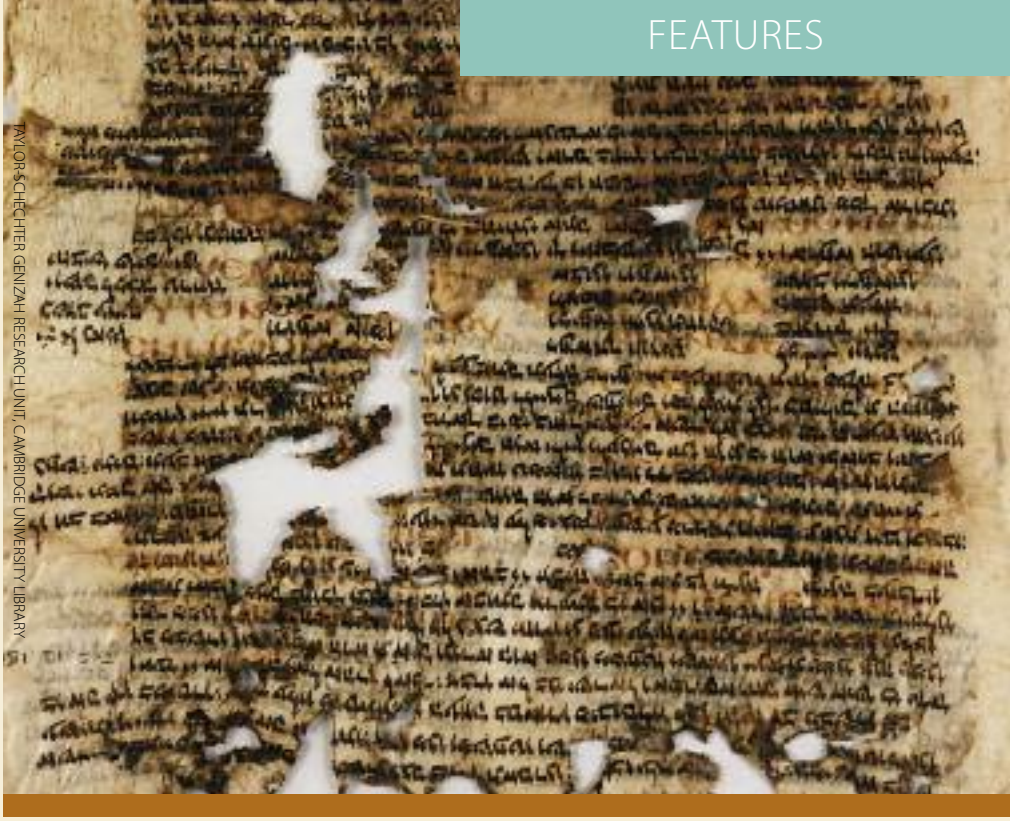
The Unit has been digitising manuscripts for over 10 years, and some 30,000 images will be available online by the autumn of 2009 thanks to a previous AHRC grant. This is just a beginning, however, as the US-based Friedberg Genizah Project, together with its sister charity in Canada, the Jewish Manuscripts Preservation Society, has made a substantial grant to the Library to digitise the remainder of the entire Collection – a staggering 310,000 digital images. The high-quality images will be produced over the next three years by the Library's Imaging Services Department. They will be made available online by both Friedberg and Cambridge, the latter through the University's digital repository DSpace@Cambridge, which will safely store an estimated 25 terabytes of manuscript images as a 21st-century genizah of its own.

**Dr Ben Outhwaite**

**For more information, please contact the author Dr Ben Outhwaite (genizah@lib.cam.ac.uk), Head of the Taylor-Schechter Genizah Research Unit in Cambridge University Library (www.lib.cam.ac.uk/Taylor-Schechter/). A longer article has been published online at www.research-horizons.cam.ac.uk/**

# The Greek Bible of the Byzantine Jews

**Researchers at the Faculty of Divinity are using ancient manuscript fragments to re-evaluate a forgotten episode of biblical history.**



TAYLOR-SCHECHTER GENIZAH RESEARCH UNIT, CAMBRIDGE UNIVERSITY LIBRARY

**Geniza palimpsest: Hebrew (shown upside down) written over the top of a 6th-century copy of Akylas' Greek translation (c. 125 CE) of the *Books of Kings* (shown the right way up); T-S 12.184r**

One of the greatest and most lasting achievements of Jewish civilisation in the Graeco-Roman period was the translation of the Hebrew scriptures into Greek between the 3rd and 1st centuries BCE. It was an unprecedented project: not only was it the first translation on such a scale, but it also opened up the core teachings of the Jewish religion to Jews who did not understand the sacred language, as well as to the non-Jewish world. Without this translation, it is doubtful whether Christianity could have spread as quickly and successfully as it did. The translated books – which came to be known collectively as the Septuagint, after the 70 Jewish scholars said to have translated them – became a keystone of teaching and worship for large numbers of Jews and Christians for centuries, and still constitute the Old Testament for Greek-speaking Christians today.

The study of the Christian history of these books has long been pursued in European universities. But the Jewish origin of the translations, although not entirely forgotten, has been sidelined, according to a general supposition that Jews gave up using the translations along with their use of the Greek language.

However, evidence has been unfolding to the contrary, aided by the discovery of long-lost manuscript fragments confirming that Greek Bible translations continued to be used in Byzantine Judaism. A project led by Nicholas de Lange, Professor of Hebrew and Jewish Studies in the Faculties of Divinity and Asian and Middle Eastern Studies, is spearheading this re-evaluation of a mysterious time in biblical history. It is also providing the latest instalment of a quintessentially Cambridge story.

## Rediscovering Jewish tradition

In the 1890s, the University of Cambridge was the world centre of Septuagint scholarship. Cambridge academic Solomon Schechter had returned from Cairo with the largest and by far the most important hoard of Hebrew manuscripts ever discovered (see opposite page). One of the most exciting discoveries to emerge from a first trawl through the fragments was a palimpsest, a manuscript that had been reused for writing another text. The original writing was from a handsome Greek copy of the *Books of Kings*, not in the Septuagint translation but in a later translation made in the early 2nd century CE by a convert to Judaism named Akylas. This was the first evidence of the continuous transmission of Greek Bible translations; many others were to follow.

Since the 1970s, Professor de Lange has been collecting and studying evidence for the use of Greek Bible translations by Jews in the Middle Ages. Over the past three years, these have been gathered into an online corpus (http://gbbj.org/) that, for the first time, has made the texts and analysis of them available to other scholars.

With funding from the Arts and Humanities Research Council (AHRC), the corpus is being prepared with the help of Dr Cameron Boyd-Taylor and Dr Julia Krivoruchko in the Faculty, as well as the highly specialised IT expertise of the Centre for Computing in the Humanities at King's College London. The fully searchable corpus permits comparison of each word with the Hebrew text, the Septuagint, and the fragments of Akylas' and other Jewish translations from antiquity.

## Lifting the shroud of mystery

The project will aid understanding of the Jewish tradition of Bible translation in Greek-speaking lands throughout the Middle Ages: who produced the translations, who used them, and for what purposes? How widespread was their use at different times? To what extent was it an oral rather than a written tradition? The project will offer us a rare glimpse of Byzantine Jewish life and culture, the cross-fertilisation between Jewish and Christian biblical scholars in the Middle Ages, and add to our understanding of the history of the Greek language at that time.

**Professor Nicholas de Lange**

**For more information, please contact the author Professor Nicholas de Lange (nrml1@cam.ac.uk; http://gbbj.org/) at the Faculty of Divinity.**

# The Planck satellite: looking back to the dawn of time

**The Planck satellite has just reached its orbit, 1.5 million km from Earth, on a mission to understand the origin and evolution of our Universe.**

Ariane 5 was launched successfully by the European Space Agency (ESA) on the 14 May 2009 from French Guiana. Aboard the rocket were the Planck and Herschel Observatories. Worth a combined £1.7 billion, these are two of the most expensive scientific satellites ever built by ESA. Within a few hours, the satellites had separated, and the Planck satellite (named after the German Nobel Laureate Max Planck) began the journey to its current orbit 1.5 million km from Earth in the opposite direction to the Sun. For the next two years, the satellite will complete a full scan of the whole sky every six months.

Researchers at the Cambridge Planck Analysis Centre (CPAC), which is spread between the Institute of Astronomy, the Kavli Institute for Cosmology, the Department of Physics, and the Department of Applied Mathematics and Theoretical Physics, are working in partnership with over 40 institutes as part of the pan-European Planck collaboration. Professor George Efstathiou, Director of the Kavli Institute, has been part of the project since its inception in 1993, and is one of the 10-member international Planck Science Team whose task is to monitor and direct the Planck satellite's scientific programme.

## The ultimate questions

The Planck satellite has been designed to answer some of the most important questions of modern science – how did the Universe begin, how did it evolve to the state we observe today, and how will it evolve in the future? The satellite is equipped with powerful microwave detectors chilled to close to absolute zero, and its objective is to provide a major source of information to test theories of the early Universe and the origin of cosmic structure.

Cosmologists have a much clearer picture of the Universe than they did 15 years ago. According to current understanding, the Universe is spatially flat, about 13.7 billion years old and is mostly composed of mysterious 'dark energy' (an energy form that is thought to account for the Universe's accelerating expansion). Much of this information has come from studying the remnants of the radiation that filled the Universe immediately after the Big Bang, which we observe today as the cosmic microwave background (CMB). But cosmologists believe that only a fraction of the information has been extracted so far, limited by the sensitivity of detectors used to study it.

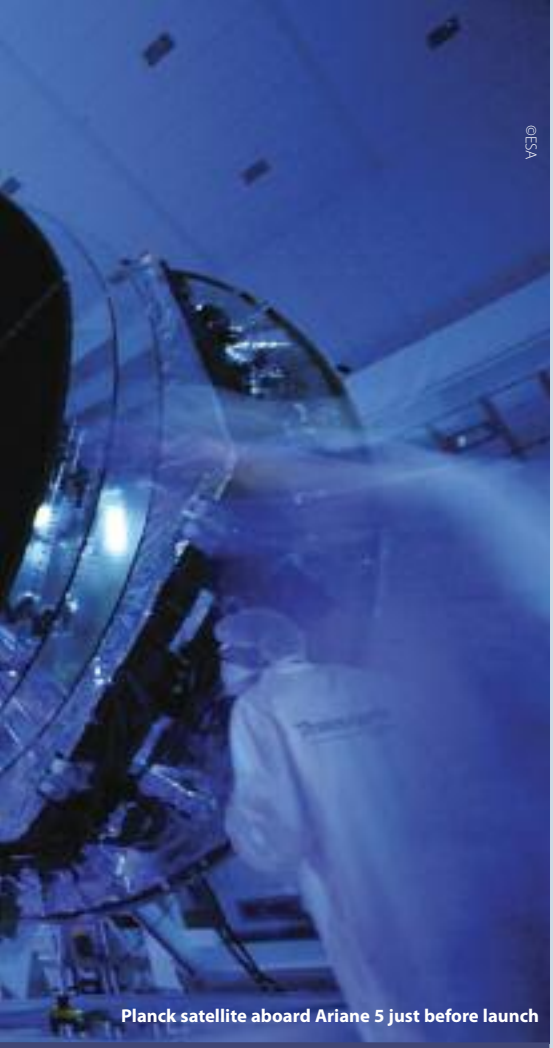
This is where Planck comes in. By carrying highly sensitive detectors, Planck is designed to measure tiny temperature fluctuations in the CMB (often called 'CMB anisotropies') with the highest accuracy ever achieved. These fluctuations are thought to have been generated within $10^{-35}$ seconds of the Big Bang. At these early times, the billions of galaxies that we see today would fit into a volume about the size of a grapefruit.

Very little is known about the Universe at times close to the Big Bang. Planck may show that our Universe has more than three spatial dimensions, or that it is one of many others, and may even uncover what happened before the Big Bang.

## Probing the data

By the end of the two-year mission, Planck will have extracted a wealth of cosmological information from the CMB. One of many vital mission components is the data analysis and simulation software, which is being developed by scientists at a number of European institutions including CPAC. Cambridge researchers will be actively involved in the scientific interpretation of the data sent back from Planck and will also be responsible for providing a catalogue of the many hundreds of galaxy clusters within the Universe.

To do this requires substantial computing power and the University's Darwin supercomputer in the



Planck satellite aboard Ariane 5 just before launch

High-Performance Computing Service will be essential for the analysis of the terabytes of data streamed back to Earth from Planck (see panel).

The goals for the Planck satellite are ambitious but the returns could be spectacular. Planck will establish real facts where once there were unknowns and has the potential to uncover completely unanticipated phenomena that could revolutionise our understanding of physics.

**Professor George Efstathiou**

**For more information, please contact Professor George Efstathiou (gpe@ast.cam.ac.uk), Director of the Kavli Institute for Cosmology (www.kicc.cam.ac.uk/). The Cambridge contribution to the Planck consortium has been funded by the Science and Technology Facilities Council (STFC).**

## Cambridge supercomputing

### Darwin, the University of Cambridge's supercomputer, has the power to process hundreds of terabytes of raw data in a matter of weeks.

Cambridge's High-Performance Computing Service (HPCS) is home to a 20-tonne supercomputer called Darwin. Comprising 585 Dell servers and 2,340 processor cores, Darwin is one of the fastest computers in the UK, and a forthcoming upgrade will increase this yet further, taking the processing power from 20 to 30 teraflops.

Darwin is a central resource that is open to all research staff within the University. It processes complex simulations for a wide variety of research projects: from simulating crack propagation in materials modelling and analysing air flow over turbine blades, to interrogating raw data sent back by the Planck satellite.

### Value for money

The HPCS is a self-sustaining cost centre, whereby users are charged at point of use of the system and the service costs are covered by a combination of industrial sponsorship and academic income from research grants. The service has been running this model for just over two years and is now almost entirely self-sustainable. Dr Paul Calleja, Director of the HPCS, explained the significance of this attribute: 'This is an important achievement because it underpins the viability of the service for future years even with hard economic times ahead within the public sector.'

The cost model and overall service delivery strategy of the HPCS has been successfully constructed with value for money as one of the primary goals. 'This is a key reason why many groups and departments within the University are looking to outsource their high-performance computing and research computing requirements to the HPCS,' said Dr Calleja. 'Not only does the facility maximise the resources available to staff but it also reduces the overall cost base of departments.'

Free usage of the system is also supported by the HPCS, both to allow new users to develop their skills and to enable pre-existing users a level of continuity if they fall between grant lines. Moving forward, the HPCS will always ensure that there is adequate free access to the system within the cost model but will link free access to grant-writing activity to guarantee that the entire user community is helping to underpin the financial stability of the service.

### Research productivity

The HPCS offers a wide range of general research computing services and support options that map well to the varied workflow processes required by different projects; such flexibility and range of services greatly increase the productivity and output of its users.

Facilitating new and world-class computational science for research purposes is the primary mission of the HPCS, as amply demonstrated by the wide range of research publications being produced by its user community. For users such as the Cambridge Planck Analysis Centre, the kinds of cosmological breakthroughs anticipated with the Planck satellite would be impossible to achieve without this level of supercomputing power.

**For more information, please contact the HPCS Account Manager, Kamila Lembrych (kl341@admin.cam.ac.uk) or visit www.hpc.cam.ac.uk/**

# Young people, morality and crime

**A study at the Institute of Criminology links moral context to the scene of the crime.**

Building on the premise that crime and morality are two sides of the same coin, a study funded by the Economic and Social Research Council (ESRC) based at the Institute of Criminology is set to reveal some fascinating findings from six years of research into the links between social environments and young people's attitudes to crime.

## The crime conundrum

In today's highly regulated society, the significance of rules and rule-breaking is of great interest. It is a universal truth that any crime is a breach of the moral code as defined by law, yet there has been surprisingly little work to test the influence of morality on deviant behaviour. With nearly half of all crimes committed by less than a tenth of all criminals, it is vital to understand what leads certain individuals to offend and some to become persistent criminals.

The key to preventing crime is to identify what motivates individuals to break the rules that define right and wrong. This demands a better understanding of the interplay between two key factors: first, how different social environments and experiences affect an individual's morality; and second, the role of exposure to moral contexts that are conducive to crime.

## Situational Action Theory

Professor Per-Olof Wikström, from the Institute of Criminology, has developed Situational Action Theory (SAT) to explain crime as moral action. His theory suggests that individuals' personal moral rules differ, as do the moral emotions such as shame and guilt that they attach to those rules. Different rules apply to different circumstances and are enforced to different degrees: this represents the moral context.

To explain why people break rules, we need to clarify how their personal morality interacts with the moral context of different social environments to indicate which types of people will offend and in what circumstances. Unlike other action theories, SAT suggests that actions can be deliberate, whereby various alternatives are considered, or habitual when people see only one course of action. Although habitual choices are rarely studied in criminology, the theory suggests that they may contribute significantly to persistent offending.

## The Peterborough Study

The theory is being tested through the Peterborough Adolescent and Young Adult Development Study (PADS+), under Professor Wikström's direction. It began in 2002, when the participants were aged 11. Randomly selected, they represented one-third of their age group living in the medium-sized city of Peterborough, UK. Following interviews with their parents, the participants have been interviewed annually since 2004, with two more data waves planned for 2010 and 2012. By 2012, approximately 700 participants will have been tracked from ages 11 to 21 – a critical 10-year period for personal and social development.

Reference data include information about personal characteristics, moral rules, emotions and self-control, plus details about home, school and neighbourhood experiences. Participants' decision-making abilities are measured annually via neurocognitive tasks. They also complete an innovative space–time budget, which records where they were every hour; the setting; their geographical coordinates; who they were with; what they were doing; and their involvement in any risky behaviour, such as crime, victimisation and drug use. These data are used to measure how much time participants spend, and how they act, in certain types of social environment.

In 2005, the team gathered detailed geographically coded data about the city's social environments via the Peterborough Community Survey. By linking this to the space–time budget data, exposure to specific social environments – such as disadvantaged areas or those with poor social cohesion and trust – could be measured. It is the first criminological study of this type to use such a detailed measure of exposure to different types of social environments beyond the core home environment.

Furthermore, the longitudinal profile of the data will enable the researchers to evaluate the impact of change during adolescence when young people gain mobility and independence, so increasing their exposure to diverse social environments. The team can explore how personal changes influence criminal involvement, for instance, when they start offending, how often they offend and whether and when they stop.




## Early findings back moral position

Early findings support SAT predictions. Personal morality appears to play a key role in influencing which young people offend, while moral context influences where they offend. Young people with weaker moral rules report more offences, as do those who spend time unsupervised in places with unstructured peer-group activities.

Previous research has highlighted the importance of self-control in offending. The PADS+ findings qualify this, showing that self-control is only important for young people with weaker moral rules and emotions who see crime as an option. Young people who don't consider offending don't need to exhibit self-control; their morality alone explains why they don't offend. This strengthens the case for further research and points to interventions based on moral education in addition to, for example, cognitive skills training.

As predicted by SAT, the findings reveal an interaction between personal traits and exposure to different social environments. Young people with strong moral rules and emotions rarely offend, no matter how long they spend in disadvantaged social environments. However, the more exposure young people with weak moral rules have to disadvantaged social environments, the more they report offending. This has important implications for crime prevention, suggesting that environmental interventions may be most effective for those with a propensity to offend.

Finally, the findings show that changes in moral values and changes in exposure to different social environments relate to changes in offending. This highlights the need to identify critical points in the development process that can be manipulated to achieve the best outcomes. Further analysis will explore how emotions and moral values develop, how they are externally influenced and how to halt the emergence of disadvantaged social environments.

## Implications for the future

While much criminological research has focused on personal traits like self-control, attention deficits and psychopathy, this study demonstrates that crime has a strong social dimension. The data show that young people who spend more time in disadvantaged social environments with greater disorder, less social cohesion and less trust are more likely to offend. Because it is often quicker and easier to change social environments than individual traits, the findings reinforce the need for more research into the link between social environments and crime.

As one of the first studies to analyse changes in young people's moral rules, emotions and behaviours from both a personal and social perspective, the PADS+ data will be invaluable in better understanding which types of people tend to commit crimes in certain types of social environments. Although these findings support early interventions, such as moral skills training and careful supervision of social environments, they also suggest that change can be implemented at any stage of life, pointing to new and neglected avenues for research and intervention.

**Professor Per-Olof Wikström**

**For more information, please contact Professor Per-Olof Wikström (pow20@cam.ac.uk) at the Institute of Criminology or visit www.pads.ac.uk/**

**Energy giant BP looks to its engagement with universities like Cambridge to help stay connected to cutting-edge research in science and technology.**

'As head of BP's research and technology portfolio, my job is to ensure that BP has the technology it needs to contribute to the world's future energy demands,' said David Eyton, BP Group Head of Research & Technology and Executive Sponsor for Cambridge. 'As part of this, we work closely with a handful of excellent academic centres like Cambridge to keep us plugged into the fast-changing world of science and technology.'

BP's relationship with the University, which stretches back through the past century, was recently formalised by the signing of a Memorandum of Understanding (MoU). 'The MoU,' David Eyton explained, 'embraces all of our current interactions with Cambridge at a strategic level – from research activities, through policy development and training, to recruitment – as well as laying the groundwork for mutual support and development so that the relationship can fulfil its greatest potential.' These interactions are being overseen by Andy Leonard in his role as BP's Vice-President for Cambridge.

## Valuing research

BP's annual spend for 2009 across the University is £3.6 million, of which approximately £1 million is funding technical research and the remainder is principally funding endowments and scholarships.

The company's main channels of engagement are the BP Institute for Multiphase Flow (see centre panel), established in 2000 with a £22 million endowment from BP, and Judge Business School through the Centre for India and Global Business and the Cambridge Centre for Energy Studies (see page 19). BP has also had long and fruitful collaborations elsewhere in the University, especially with the Bullard Laboratories within the Department of Earth Sciences (see far-right panel).

Several areas of applied research activities in Cambridge have brought world-class expertise to bear on practical issues that have reaped immediate benefits for BP, from exploration through to fuels and lubricants. But BP also views fundamental research as strategically important: 'Although fundamental research can take years from invention to commercialisation, it also has the potential to yield something truly significant,' said Eyton. 'The University has a fabulous track record of creating important knowledge and that is one of the reasons we are investing in Cambridge. As a business, we have to stay competitive and invest in areas that we believe will benefit our shareholders.'

## Recruiting the best

Recruitment is very much part of the strategic relationship with Cambridge. 'The people we recruit today could have a profound impact on the company over many decades,' explained Andy Leonard, 'so we need to ensure that the highest quality students are exposed to the range of employment opportunities within BP.' Also of importance, partly from a recruiting perspective, is the large number of scholarship programmes BP runs for research students, mainly in collaboration with the Cambridge Commonwealth and Overseas Trusts. This year, BP has made job offers to 20 graduates and 17 interns in Cambridge, as well as partially funding 49 research scholarships.

## Recognising opportunities

'The key to success in strategic relationships is to create situations where there is genuine mutuality,' said Eyton. 'We want the relationship with Cambridge to acheive its greatest potential and to progress the strategic aims of the University and BP.' The company is also keen to support the strengthening of links between universities such as Cambridge, the Massachusetts Institute of Technology (MIT) and Tsinghua University in Beijing, predominantly with regard to finding new forms of low carbon energy and moving towards a more sustainable energy landscape in the world.

'I am a big believer in investing in places like Cambridge that have a proven record of success,' explained Eyton. 'I also think that we have even more to discover in terms of opportunities for productive interactions. I'm delighted to say that we are on this journey.'

**For more information about BP, please visit www.bp.com/**

BP Institute for Multiphase Flow

# BP Institute for Multiphase Flow

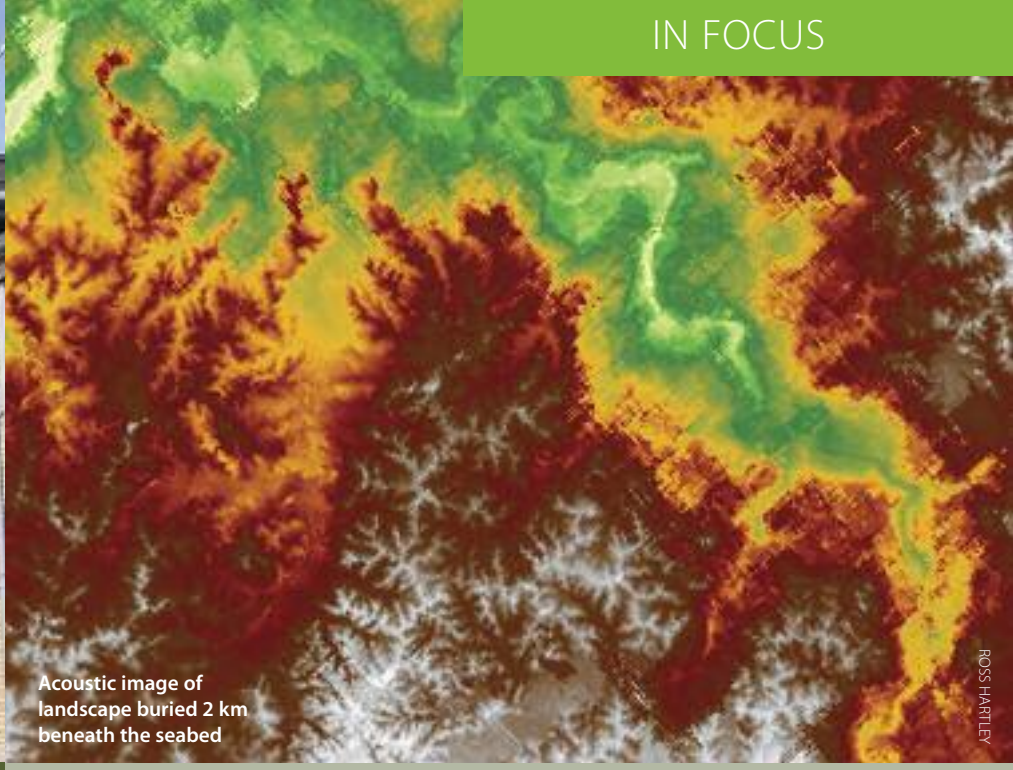
**Understanding flow – whether it's of oil, air, lubricants, lava, seawater or $CO_2$ – lies at the heart of Cambridge's BP Institute.**

Endowed by a £22 million donation from BP, the BP Institute for Multiphase Flow (BPI) was created in 2000 with the explicit intent of hosting research teams from five departments within the University: Applied Maths and Theoretical Physics, Chemical Engineering, Chemistry, Earth Sciences and Engineering.

Today, a multidisciplinary team of almost 40 academics and students is working to understand how gases and fluids move. Multiphase flow is an area of great interest to BP as it underpins all parts of its business: from enhancing oil recovery to delivering it to customers, and from refining hydrocarbons to investing in a low carbon future.

For the BPI, engagement with BP enriches research in a very practical sense, as Professor Andy Woods, Director, explained: 'Our close working relationship with BP gives us in-depth exposure to technical challenges in the industry as well as unparalleled access to field data that would be impossible for us to collect. This means that we can frame research directions that are fundamentally interesting to us as academics and can also solve problems that are of relevance to the industry.'

Currently, a large pan-Institute project is analysing the interactions between fluids and solids in oil fields to understand the physical chemistry that controls how much



Acoustic image of landscape buried 2 km beneath the seabed

ROSS HARTLEY

oil can be recovered as a function of the salinity of the water used to pump it from the well. Other projects vary from analysing the molecular basis of how lubricants work to understanding how volcanoes erupt, and from addressing questions about the long-term storage of $CO_2$ in redundant oil wells to determining how you can control heat transfer in buildings through natural convection. This latter research theme led in 2006 to the spin-out company E-Stack, which was set up to commercialise a low energy ventilation system that uses natural convection to keep the interior temperature of buildings buffered from exterior changes.

Professor Woods sees the link between basic research and industrial applications as key to research at BPI. 'We determine our own research programme and our prime interest is in answering fundamental questions about flow. But we're also looking at how this impacts on 'real world' applications because this in turn informs a whole new set of fundamental questions and, if we're lucky, the development of unforeseen applications.'

**Professor Andy Woods**

**For more information, please contact Professor Andy Woods (andy@bpi.cam.ac.uk) or visit www.bpi.cam.ac.uk/**

# 'Elephant hunting' with less risk

## Cambridge scientists are helping to improve the chances of success of oil exploration in some of the Earth's most hostile frontiers.

Increasingly, companies such as BP are exploring for oil in very deep waters along the edges of the continents. Drilling beneath the seabed through rocks down to depths of 4 km and in water depths of nearly 3 km is both risky and costly. Scientists at the Bullard Laboratories in the Department of Earth Sciences are helping to reduce the uncertainty of finding oil in these hostile environments by developing an understanding of the structure and evolution of the Earth's tectonic plates.

Dr Nicky White leads a project funded by BP that studies the prime focus of deep-sea oil exploration: submerged continental margins at the edges of ocean basins. It is in these regions that the thinning of the tectonic plate over many millions of years has generated rock layers and structures that have favoured oil formation and trapping. Over time, organic-rich rocks produce oil, which is expelled upwards, where it fills the pore spaces of a reservoir rock and is trapped in place by overlying impermeable rocks. For oil generation, it is crucial that the organic-rich rocks have been subjected to suitable temperatures for the right amount of time (thermal maturation) and it is here that Dr White's group is providing invaluable new understanding.

The laboratory's track record of active involvement with BP reaches back to Professor Dan McKenzie, whose fundamental work on plate tectonics in the 1970s and 1980s helped BP undergo a major refocus on exploring sedimentary basins around the world. Within 10 years, BP's search for giant oil fields in frontier areas – known in the industry as 'elephant hunting' – resulted in a string of exploration successes in places such as the Gulf of Mexico, Angola, Egypt, Russia and Azerbaijan.

Dr White's work continues this pioneering geophysical research, generating sophisticated numerical models of sub-surface conditions. Working with BP has been key to the research, as Dr White explained: 'A quantitative understanding of thermal maturation is only possible with access to terabytes of high-quality seismic data. BP acquires amazing sub-surface images that we then interpret and model.'

With billions of dollars at stake, reducing uncertainties in oil exploration will help BP to continue their century-long success in exploration and production, bringing new reserves on stream to compensate for depleting global inventories.

**Dr Nicky White**

**For more information, please contact Dr Nicky White (nwhite@esc.cam.ac.uk).**

# Dr Abigail Brundin

**Renaissance scholar Dr Abigail Brundin, Senior Lecturer in the Department of Italian, has been awarded an 'I Tatti' Fellowship from Harvard University, enabling her to spend time exploring 16th- and 17th-century Florentine archives. She hopes to shed light on a turbulent period in Italy's literary history, when poets and writers laboured in the face of religious censorship.**

Having been chosen as one of 15 academics awarded the prestigious 'I Tatti' Fellowship each year, of which only half are open to non-US scholars, Dr Brundin is embarking on a year of study in Florence at the Harvard University Center for Italian Renaissance Studies.

She will be continuing her examination of Italian literature from a period dominated by censorship of creative expression and literary production by the church and, yet, as it is now becoming apparent, characterised by individuals who resisted the pull of literary stagnation. 'If you look at traditional historiographies of the period known as the Counter-Reformation, it has been widely written off as a time where nothing very exciting happened in terms of Italian literature,' she explained. 'But there is growing evidence of patterns of resistance to censorship, including the existence of groups of outspoken and experimental writers.' Dr Brundin aims to redress the balance by exploring this under-researched area, enabling a reappraisal of the effects of censorship on literature of the time.

Dr Brundin relocates to Florence with her partner and three children, aged 5 months, 5 years and 7 years, on what she happily anticipates will be an adventure for them all. From an academic perspective, she is relishing the opportunities afforded by the chance for a sustained period of archival work, which, as she says, 'is always a voyage of discovery.'

**What would others be surprised to learn about you?**
*I'm a really atrocious speller. I was never taught to spell properly at my rather hippy primary school and I used to sound words out phonetically. Word spellcheck is now my best friend. It's interesting that I've ended up working in Italian, which is an entirely phonetic language – basically, as long as you know what a word sounds like, you can spell it!*

**Who or what inspires you?**
*In relation to my work, I am inspired by a desire to take a fresh look at the 'grand narratives' of literary history to uncover the marginal or less obvious voices and perspectives. Thus far, this has meant the voices of women, and of Italians who were interested in the Reformation and its ideas. On a personal note, I always feel inspired by the beautiful landscape of Cornwall, where I've been going every year since I was born and now take my own children.*

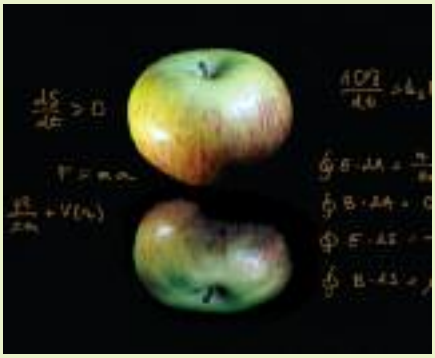
**Have you ever had a Eureka moment?**
*Genuinely, I think the answer is no. I don't know if they really occur in my field of work – it's more about incremental understanding of the way things happen, a subtle and gradual creeping towards a greater insight. I have come across some arresting pieces in the archives, but I've yet in my career to stumble upon that life-changing document, that missing piece of the jigsaw – maybe next year!*

**What's the best piece of advice you've ever been given?**
*That you shouldn't feel that a piece of work has to be definitive. A thesis or a paper is really a snapshot of where your thinking has arrived at as a result of your research up till that moment. But it's not necessarily the final answer – if you go back to it in a year's time, you might have other information that causes you to interpret your findings in a new way. I see some doctoral students blocked by the inability to let go of something because they don't feel that it's finished, but actually it's never finished. In research, you need to constantly respond to new information as you find it.*

**If you could wake up tomorrow with a new skill, what would it be?**
*I would love to have really good Latin. It would mean that when I come across documents that look like they really matter my heart doesn't sink at the number of hours I'm going to have to put into deciphering them!*

**What is your favourite research tool?**
*Possibly the internet – it's wonderful today how much is digitised and online, from generous scholars who've put their life's work online in searchable format, to rare and inaccessible manuscripts that are available at the touch of a button. But, phenomenally useful as this is, my favourite research tool has to be the archive. I still cherish the incredible experience I had travelling to Rome for the first time as a doctoral student, getting my reader's pass for the Vatican Archives, and venturing into the unknown. Nothing replaces that excitement of enquiry when you're on the spot, holding the books and papers in your own hands. Thrilling!*

# Forthcoming events: Save the dates!



## 22–23 September 2009

### Physics of Living Matter 4
### Centre for Mathematical Sciences, Cambridge

The 4th Symposium on the Physics of Living Matter is part of an initiative at the University of Cambridge to underpin the interface between the physical and biomedical sciences. This year, the Symposium will be held in conjunction with the University's Centre for Systems Biology and will cover predictive biology, dynamical assemblies of living matter and organisation of biological networks. The keynote speaker is Professor Uri Alon of the Weizmann Institute. Please visit www.gen.cam.ac.uk/plm/ for more information and http://tinyurl.com/nrbcvy/ to register.

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## 1 October 2009

### Horizon Seminar 'Energy & Environment'

HORIZON

### Centre for Mathematical Sciences, Cambridge

There is an imperative need for a shift in society's approach to climate change and energy if the risk of serious social, environmental or economic harm is to be limited. This Horizon Seminar will showcase the latest research from the University of Cambridge, highlighting the need for key infrastructure integration as well as the importance of long-term decision making for sustainable growth. Please visit www.rsd.cam.ac.uk/events/energyandenvironment/ or email horizon@rsd.cam.ac.uk for more information and to register.


## 19–23 October 2009

### International Open Access Week
### Cambridge University Library

The Open Access movement worldwide has been gathering pace as top-tier universities embrace the effort to provide free online access to research literature and data. To support understanding of Open Access, the University Library is organising a number of events during the International Open Access Week in October, built around DSpace@Cambridge (www.dspace.cam.ac.uk/), the University of Cambridge's institutional Open Access repository. Please visit www.lib.cam.ac.uk/create_change/events.html for more information.

ELLA WOOLNER

## 21 October–1 November 2009

### Cambridge Festival of Ideas: 'Centuries of Ideas'

Celebrating the arts, humanities and social sciences, Cambridge's Festival of Ideas brings together 100 free events in history, literature, languages, drama and art. This year's Festival looks back at ideas that have shaped the world and forward to the challenges for the future. Watch fascinating performances and discover how the study of arts, humanities and social sciences helps us to understand vital issues past, present and future. Please visit www.cambridgefestivalofideas.org/ or email cfi@admin.cam.ac.uk for more information.

## 8–21 March 2010

### Cambridge Science Festival: 'Diverse Science'

Join us for the UK's largest free science festival, exploring subjects from astronomy to zoology, with demonstrations, hands-on experiments, talks from leading scientists, and visits to University and partner facilities. The 2010 Science Festival's theme is 'Diverse Science', to tie in with the International Year of Biodiversity. Over 180 events will be on offer, with topics designed for families, adults and sixth-formers. The full programme will be available at www.cambridgescience.org/ from January 2010.

# Your way into Cambridge

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