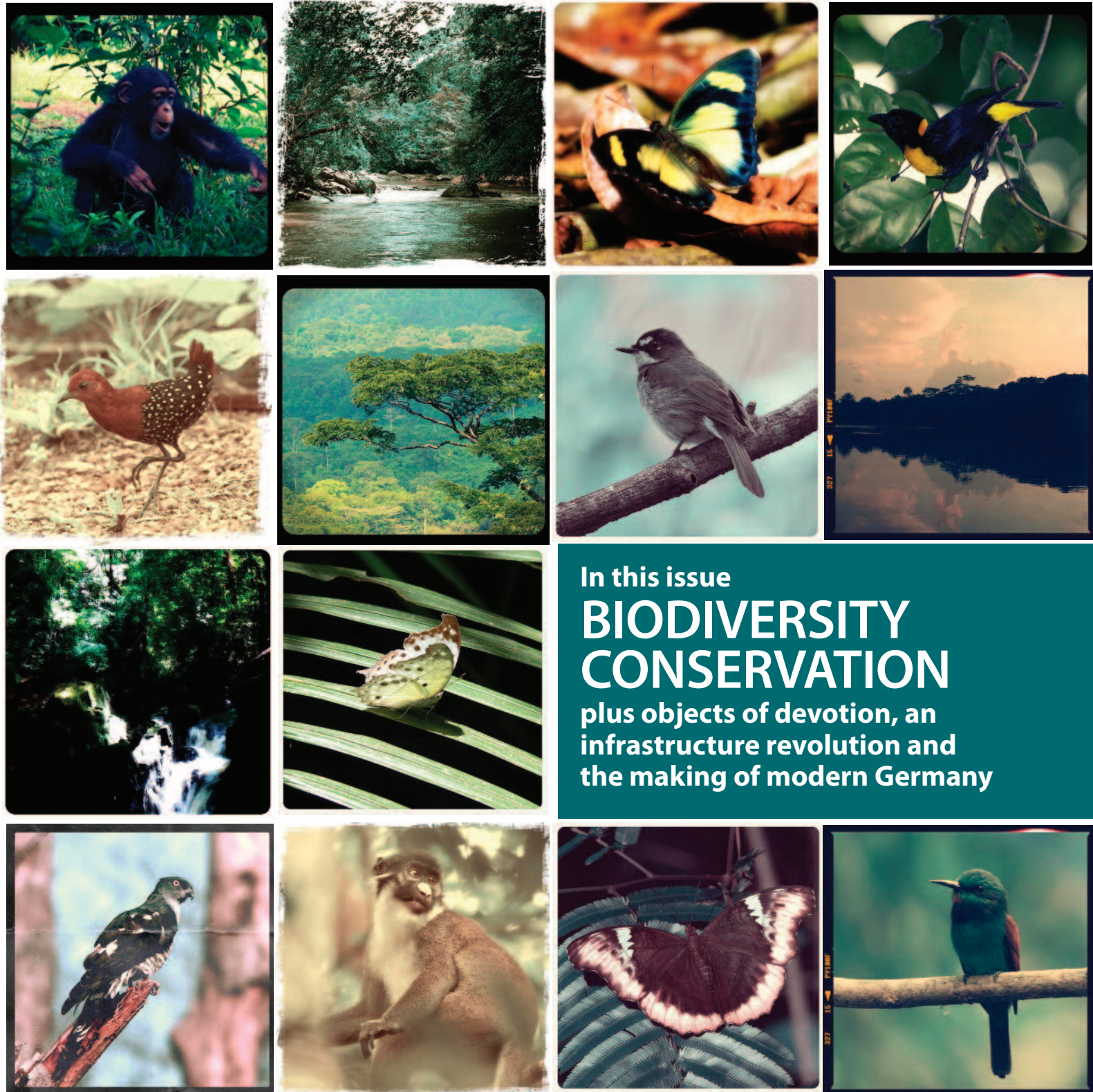


RESEARCH HORIZONS



In this issue
**BIODIVERSITY
CONSERVATION**
plus objects of devotion, an
infrastructure revolution and
the making of modern Germany



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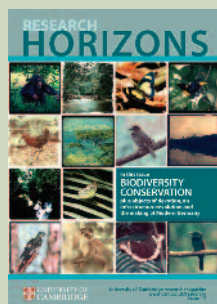
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Images of Gola Forest, Sierra Leone, a biodiversity hotspot of global significance. Read about innovative approaches for protecting the forest's future on page 8. Original photography: David Monticelli, Jeremy Lindsell, Koen Leuvelde; image manipulation: Fred Lewsey and Nick Saffell.

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Biodiversity conservation



MARK MINISZKO

Cambridge is famous as the centre of 'Silicon Fen' – the cluster of high-tech businesses drawn together geographically by the benefits of a world-leading research-intensive University and rich networking opportunities. Much less well known is the fact that Cambridge is home to one of the world's largest clusters of people and institutions working to understand and conserve global biodiversity.

Life on Earth is at risk from an unprecedented rate of environmental change that threatens the natural resources on which humanity depends. Biodiversity – the genes, species and ecosystems that comprise nature – provides food, fuel, medicines and other vital 'ecosystem services', along with countless intangible benefits, for society.

But biodiversity is in steep decline, and its sustainable management is a major challenge for the 21st century. In response, Cambridge researchers from diverse disciplines, along with conservation practitioners and policy experts – all linked to global networks – have created the Cambridge Conservation Initiative (CCI). As a partnership between the University and world-leading conservation organisations¹, CCI aims to help secure a sustainable future for biodiversity and humanity through interdisciplinary and innovative research, learning, leadership and action.

Some of the collaborations between researchers and practitioners described in this issue of *Research Horizons* illustrate how this University Strategic Initiative is addressing global challenges. Achieving food security while conserving the raw materials provided by biodiversity, reducing carbon emissions and alleviating poverty through forest conservation, and measuring the benefits an area's biodiversity brings to society are but three of 14 projects supported through the CCI Collaborative Fund that offer solutions to real-world problems.

Similarly, we see how innovative thinking can begin to transform the landscape of biodiversity conservation. Studies which identify new emerging issues for biodiversity conservation, which explore whether computer gaming can reconnect people to nature, and which draw on disciplines as diverse as business, archaeology and English show how Cambridge offers a distinct and often novel approach to conservation.

Over the next three years, our vision is to create an interdisciplinary conservation campus at the heart of the University, bringing together over 500 professional conservationists from across organisations and University departments, in a centre of international conservation excellence. The campus will facilitate and sustain the flow of conservation research and practical solutions, enhance global conservation capacity and leadership, and help to transform public understanding of nature.

Dr Mike Rands
 Executive Director, Cambridge Conservation Initiative

¹CCI partners: BirdLife International, British Trust for Ornithology, Cambridge Conservation Forum, Fauna & Flora International, International Union for Conservation of Nature, RSPB, TRAFFIC International, Tropical Biology Association, UNEP World Conservation Monitoring Centre, University of Cambridge

Cambridge gives Newton papers to the world

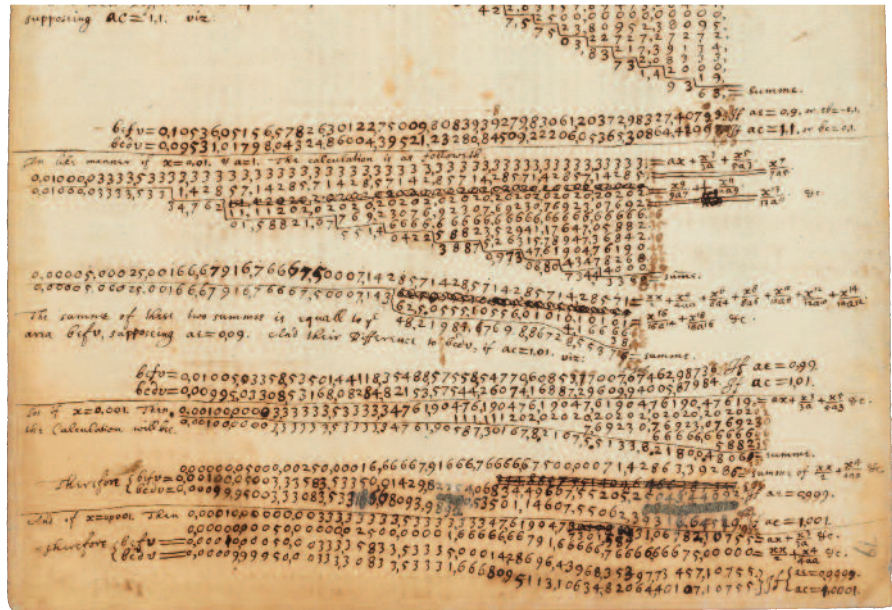
Cambridge University Library has launched its new digital library by making available online Isaac Newton's papers, including his own annotated copy of his *Principia Mathematica*.

The Library holds the world's largest and most significant collection of the scientific works of Isaac Newton (1642–1727), described by many as the greatest and most influential scientist who ever lived. Now, more than 4,000 pages of its most important Newton material has been uploaded to the Cambridge Digital Library to view and download anywhere in the world, with more to follow over the next few months. Within a day of its announcement, the site had recorded millions of hits.

The University Library aims to develop a digital library for the world and will move on from Newton to some of its other world-class collections in the realms of science and faith. These will include the archive of the celebrated Board of Longitude, a selection from the Darwin papers and some of the earliest surviving religious manuscripts.

"Over the course of six centuries Cambridge University Library's collections have grown from a few dozen volumes into one of the world's great libraries, with an extraordinary accumulation of books, maps, manuscripts and journals," said University Librarian Anne Jarvis. "These cover every conceivable aspect of human endeavour, spanning most of the world's cultural traditions."

The digitisation of the Newton papers and development of the sophisticated technical infrastructure that will underpin the new digital library were made possible by a £1.5 million lead gift from the Polonsky Foundation



Some of Newton's early calculations for determining the area of a hyperbola, 1665; MS.Add.3958 folio 79r

in June 2010. For the digital launch of the Newton papers, the Library has been aided by funding from JISC (Joint Information Services Committee), which has enabled the linking of the Library's high-resolution facsimiles with transcriptions produced by the Newton Project at the University of Sussex.

"Now, anyone, wherever they are, can see at the click of a mouse how Newton worked and how he went about developing his theories and experiments," added Grant Young, Digitisation Manager at the Library.

"Newton's copy of his *Principia* shows how methodically he worked through his text; marking alterations, crossing out and annotating his work in preparation for the second edition. Before today, anyone who wanted to see these things had to come to Cambridge. Now we're bringing Cambridge University Library to the world."

For more information about the Cambridge Digital Library, please visit <http://cdl.lib.cam.ac.uk/>

Cambridge-Elan Centre for Research Innovation and Drug Discovery launched

World-leading researchers will work together on therapeutic advances in neuroscience.

The Cambridge-Elan Centre, which will be located at the University, will provide a highly interdisciplinary environment uniquely positioned for delivering world-leading translational research focused on innovative therapies for Alzheimer's and Parkinson's diseases.

For more than 10 years, Cambridge scientists have been engaged in research to understand the fundamental molecular origins of neurodegenerative disorders such as Alzheimer's and Parkinson's diseases. The primary goal of the new Centre will be to extend these activities to discover novel compounds and to characterise the fundamental physico-chemical mechanisms by which they alter the behaviour of proteins associated with neurodegenerative disorders.

Based on this understanding, and with the help of scientists in Elan who are

world leaders in the development of therapies to combat neurodegenerative disorders, these compounds will be translated into new treatments to prevent such diseases. A new ten-year agreement paves the way for a long-term collaboration between Elan and the University of Cambridge.

The process of bringing together researchers at the University of Cambridge and at Elan has already created novel insights and opportunities in drug discovery. The new Centre builds on the successes of this initial interaction to establish a long-term relationship to lead to novel and effective therapies for the most debilitating, costly and rapidly proliferating diseases in the modern world.

Speaking about his relationship with Elan and the launch of the Cambridge-

Elan Centre, Professor Christopher Dobson FRS, the John Humphrey Plummer Professor of Chemical and Structural Biology at the Department of Chemistry, said: "I believe that we are creating a Centre that will become globally recognised for innovation. Our collective expertise, proven ability to collaborate and open innovation model provide an exciting basis for the future. The new Centre will bring together the skills of scientists working in an academic institution and in a biotechnology company to develop new and more effective therapies for some of the most devastating and increasingly common human diseases."

For more information, please contact Professor Christopher Dobson (cmd44@cam.ac.uk).

Weaving electronics into the fabric of our physical world

Professor Arokia Nathan has taken up a new Chair in Engineering at the University, where he will be exploring electronics that could turn science fiction into reality.

The integration of electronics with materials opens up a world of enormous possibilities, the surface of which is just being scratched. From interactive paper to clothing that generates energy and lightweight material with X-ray capabilities, the weaving of electronics into everyday materials opens up a world of opportunities.

The Electrical Division in the Department of Engineering is leading the charge for Cambridge, both in terms of fundamental research and application within industry. To aid this approach, the University has recently recruited Professor Arokia Nathan from University College London (UCL) to a new Chair of Photonic Systems and Displays.

Nathan, a world leader in the development of display technology, will work between the three primary groups in the Electrical Division (electronic materials, photonics and energy), acting as a conduit and catalyst for ideas and research.

"For me this is a fantastic opportunity to collaborate with researchers at the top of their game, working on this idea of systems that can integrate functionality such as communications and energy into materials to enhance everyday life," he explained. One of his primary visions for Cambridge is the foundation of a new Design Centre to demonstrate the potential of this technology to industry through prototyping and to encourage investment from around the world.



Electrical Division, Department of Engineering

Initially, Nathan and colleagues within the Division will be developing electronic systems that can be seamlessly layered on to a material or substrate, such as plastic or polyester, with embedded transistors and sensors for transmitting and receiving information. While at UCL, Nathan and a team of collaborators from CENIMAT/FCTUNL, Portugal, demonstrated the first inverter and other circuit building blocks on a piece of paper, representing the first step towards animated

images and videos on magazine pages.

"With these non-conventional materials you have a great deal of freedom," he explained. "We believe this approach to circuitry in substrates will lead to the creation of smart substances, and once you start thinking about the possible applications, the possibilities are endless!"

For more information, please contact Professor Arokia Nathan (an299@cam.ac.uk).

Cambridge Enterprise announces 2011 results

Income generated from the University of Cambridge's commercialisation activities continued to rise in 2011, as did the number of intellectual property, consultancy and equity agreements signed on behalf of the University and its researchers.

Cambridge Enterprise, the University's commercialisation group, has recently announced its year-end results. Income from licensing, consultancy and equity transactions exceeded £10.2 million, of which £8.3 million was returned to the University, departments and researchers.

Over the past year, the Cambridge Enterprise team completed 116 licences, signed 183 consultancy contracts and returned more than £468,000 to its evergreen seed funds through equity transactions. Income from licensing increased 24% from 2009/10, income from consultancy increased by 37%, and the companies in the Cambridge

Enterprise portfolio raised more than £189 million in funding, including \$200 million raised by Plastic Logic.

One of the most exciting companies in the portfolio is Eight19, spun out from the Cavendish Laboratory in 2010. The company, which is building upon the Cavendish's expertise in the area of organic photovoltaics, has recently completed trials of its IndiGo system, a personal pay-as-you-go solar electricity system, in Zambia, Kenya, Malawi and India. The system could provide safe, sustainable and affordable power for some of the 1.6 billion people worldwide without access to electricity.

Another Cambridge company that enjoyed a highly successful year was PneumaCare, which has developed a non-contact method of measuring lung function for the one third of patients who are unable to use current methods. The company was named a winner at the prestigious Medical Futures Innovation Awards, and its product is now in use across the UK.

"Universities such as Cambridge have an important role to play in supporting an

innovation-led economic recovery, through collaborative research, technology licensing, consultancy projects and new company formation," said Dr Tony Raven, Chief Executive of Cambridge Enterprise. "The growth enjoyed by Cambridge Enterprise this year demonstrates the value that industry attaches to Cambridge research, and the contribution the University is making to our national economic recovery."

The 2011 Annual Review is available for download at www.enterprise.cam.ac.uk/



PneumaCare's PneumaScan instrument

New database for vital model organism launched

A new database promises to be an invaluable resource to scientists who study human diseases.

PomBase, a new database for the fission yeast *Schizosaccharomyces pombe*, a single-celled fungus, has been launched by a consortium of researchers at the University of Cambridge, the European Bioinformatics Institute and University College London.

Because its cell functions much like our own cells, fission yeast is an important model for studying cellular processes frequently associated with heritable diseases and cancers in humans. The organism has equivalents of human genes that are known causes of rare genetic diseases and syndromes, as well as counterparts of human genes implicated in diseases with multiple causes, such as many cancers, deafness, neurological diseases, heart disease and anaemia.

The launch of the database is the first stage of a five-year project funded by the Wellcome Trust to provide a model organism database that allows researchers around the world to participate directly in the curation process, in addition to using automated procedures based on the genetic blueprint of fission yeast.

The project uses Ensembl software for genome browsing, which is already used to present data for many other important experimental species. Novel tools and resources generated by this project will also be available to researchers working on other species, including human pathogens, to help them create similar databases.

Steve Oliver, Professor of Systems Biology and Biochemistry in the Department of Biochemistry, who is spearheading the initiative, commented: "Organism-specific database projects frequently have limited resources and large backlogs of uncurated literature. An important novel component of this project is the construction of intuitive tools to allow the research community to involve itself in database curation, and ensure that the scientific information published in their papers is visible to the entire biological research community. These tools can also be shared with other groups and implemented for their organism of interest."

The community curation initiative for PomBase will be launched in Spring 2012. The database can be found at: www.pombase.org/

Winton Programme funds new research

Two research fellows and six scholars have been appointed to work on fundamental physics research related to sustainability.

The Winton Programme for the Physics of Sustainability, which was launched in 2011 following a donation of £20 million to the Cavendish Laboratory by alumnus David Harding, has made its first scientific appointments. The donation, the largest received in the history of the Laboratory since its creation in 1874, supports the basic science needed to underpin the generation of new technologies to meet the demands made on our already strained natural resources.

Directed by the Cavendish Professor of Physics, Sir Richard Friend, the Programme has appointed six scholars embarking on PhD studentships and two fellows on five-year research programmes. These appointments mark the beginning of annual Scholarship and Fellowship appointments that will continue to bring bright physicists to work in Cambridge on exciting and novel ideas.

New Winton Fellow Dr Alex Chin's research is focused on the theoretical aspects of the new field of quantum effects in biological systems. He combines techniques from condensed matter theory, quantum optics and physical chemistry to investigate the novel physics of biomolecular processes at the boundary of quantum and classical descriptions. Chin will look for the general design principles that optimise the performance of light harvesting in natural photosynthesis, and then go on to explore how these biologically engineered strategies might be used to improve artificial technologies, such as photovoltaic devices.

Dr Siân Dutton's work involves the chemical manipulation of materials to optimise

their physical properties. As a Winton Fellow, she will work on new electrode materials for use in lithium (Li)-ion batteries, which are currently restricted to small portable electronic devices, such as mobile phones and laptop computers. To make Li-battery technology suitable for electric vehicles, and other higher power applications, she will focus on creating new electrode materials with improved performance. Her materials interests also map closely with research in the Cavendish on high-temperature superconductors and related materials.

The new appointments highlight how the Programme is helping the Cavendish to take new research directions that tap into the enormous potential for imaginative exploitation of basic physical principles, as Professor Friend explained: "A central objective of the Winton Fellowship scheme is to initiate research programmes that are new to the Cavendish that have the potential to take physics in new directions."

For more information, please contact Winton Programme Manager Dr Nalin Patel (nlp28@cam.ac.uk) or visit www.winton.phy.cam.ac.uk/



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Research, policy, practice: conservation in the round

Conservation scientists working in partnership with practitioners and policy makers are building practical tools for real-world conservation.

Just under a decade ago, a target was set by the world's governments: to slow the decline in biodiversity within 10 years. But by 2010 it was clear that global efforts had largely failed. The state of biodiversity had worsened and the ecosystem services that we rely on for food and water, a stable climate, and protection from natural disasters continue to be in jeopardy.

As plans were drawn up for a new strategic plan for the next decade, the Secretary-General of the United Nations stated that conservation efforts are all too often undermined by conflicting policies; yet, "conserving biodiversity," he said, "cannot be an afterthought once other objectives are addressed."

It's a sentiment echoed by Professor Andrew Balmford, who helps lead the University of Cambridge's Conservation Science Group in the Department of Zoology: "Conservation has to be mainstreamed. It can't be on the margins. It has to be part of policy and practice across a whole range of sectors if we are to have a chance of counteracting the rapid declines in the extent and condition of natural ecosystems."

With this in mind, he and Professor Rhys Green, the Royal Society for the Protection of Birds (RSPB)'s Principal Research Biologist and also based in the Department of Zoology, have created a series of highly effective partnerships with conservation practitioners and policy makers. These in turn have developed a suite of tools aimed at helping decision makers make informed judgments.

"Conservation has for too long suffered from key disconnects," explained Balmford. "One of the main problems is conservation research is often about biology, but the global loss of nature is really about people and what they do. To tackle fundamental questions about this relationship, quantitative research studies need to be linked to policies and practice that are capable of effecting behaviour change."

"It's an iterative process," added Green. "Smart collaborations involve policy makers

or conservation practitioners identifying the questions that need tackling and, through a dialogue with scientists, turning these into tractable research questions that researchers can answer in ways that are fit for purpose. It's conservation in the round."

Smart collaborations are a key part of the vision of the Cambridge Conservation Initiative (CCI), a pioneering collaboration between the University and eight leading conservation organisations and a conservation network based in the Cambridge area that integrates research, policy, practice and learning. Collaboration and funding through CCI have enabled Balmford and Green to address a series of questions that have important implications for global conservation and environmental management.

How, for instance, can the world respond to the growing demands for increased food production and yet conserve the raw material that biodiversity represents? A project led by Dr Ben Phalan from the Department of Zoology, and funded by the Newton Trust and CCI partners BirdLife International, RSPB and the United Nations Environment Programme World Conservation Monitoring Centre (UNEP-WCMC), is using recently developed global datasets to understand better how conflicts between conservation and farming in the tropics might be resolved.

"The expansion and intensification of agriculture are the greatest source of threat to biological diversity," explained Phalan, "and yet there is little information about how far priority areas for conservation and food production overlap. To what extent will the expansion of a particular crop threaten wild species? Are there areas where expansion of food production would be less of a problem for biodiversity?"

Following input from policy experts at a workshop held in the project's early stages

to identify focal crops, Phalan has been intersecting detailed maps of bird and crop distributions in the tropics, where agricultural expansion is most likely to affect biodiversity. Once completed later in 2012, the study will help decision makers identify the most damaging crops and the most vulnerable areas, both now and under future scenarios of agricultural change.

Another collaboration deals with the problem of how to assess the full benefits that an area's biodiversity brings to society – its 'ecosystem services'. These can include the formation of soils, provision of clean water, production of crops, regulation of climate and opportunities for recreation. Most are hard to measure without expert support. So when faced, for instance, with pressures to cut down a natural forest to increase food production, how can local decision makers accurately value the ecosystem services and weigh up the implications of the proposed change in land use?

An ambitious Ecosystem Services Toolkit to do just this is currently in its testing phase,





led by Dr Kelvin Peh from the Department of Zoology with a team from Anglia Ruskin University, BirdLife International, RSPB and UNEP-WCMC. The result is a manual (and eventually an online program) that enables non-experts to make state-of-the-art assessments of ecosystem services in their region, so that they can gauge for themselves how changes in local biodiversity will affect them.

"Linking declining levels of biodiversity with the benefits biodiversity delivers, and the pressures and responses affecting it, is crucial to taking us forward in the 'post-2010' global strategic plan for biodiversity," explained Green. A new approach to understanding this relationship has been the driving force behind yet another project – 'Linked Indicators', which, like the Ecosystem Services Toolkit project, was supported by the CCI Collaborative Fund.

The idea behind the project is that indicators of biodiversity levels are easier to understand, communicate and act upon if they are linked together in a set that connects policies to outcomes. Green, one of the

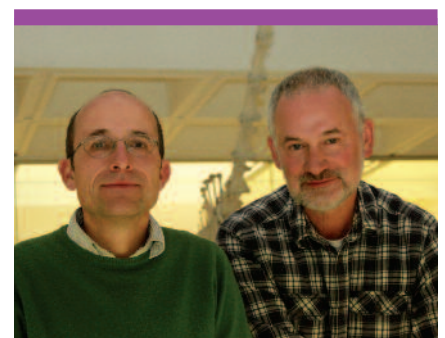
leaders of the study, explained: "It's not enough to be aware of changes to biodiversity levels. It's a bit like having a depth gauge on the *Titanic* – why would we want to know how fast things are getting worse unless we have an idea of why, and whether our attempts to do something about it are doing any good?"

The Linked Indicators concept is based on a response–pressure–state–benefit model. It proposes a set of linked indicators for each system of interest. For fisheries, for example, the pressure on marine animals from fishing and ocean temperature is related to the resulting state of marine life, as well as the benefit fishing brings in terms of employment and food, and also the policy response to reduce losses to biodiversity by creating marine protected areas. The links between such indicators represent the best available knowledge of how the ecosystem involved works and the causal relationships between its components.

Where Linked Indicators can help decision makers is to provide them with better tools to assess whether the amount and type of response to biodiversity loss have been implemented on a sufficient scale to arrest or reverse it. The study, which was developed by a team from the Department of Zoology working with BirdLife International, RSPB and UNEP-WCMC, was presented at meetings of the Convention on Biological Diversity (CBD) last year. The ideas it suggests are helping the CBD to improve its ability to track progress towards biodiversity targets post-2010.

"Even in the first few years, all of these projects have demonstrated the value for money that smart collaborations can generate," added Balmford. "By building accessible tools and strengthening the evidence base for decision makers, we can help them make wise and informed decisions for the future of people and the rest of the planet."

"Smart collaborations involve policy makers or conservation practitioners identifying questions that researchers can answer in ways that are fit for purpose."



Professor Andrew Balmford (left) and Professor Rhys Green

For more information, please contact Professor Balmford (a.balmford@zoo.cam.ac.uk) and Professor Green (r.green@zoo.cam.ac.uk) at the Department of Zoology (www.zoo.cam.ac.uk/), or visit the CCI website (www.conservation.cam.ac.uk/).

The Linked Indicators and Ecosystem Services Toolkit projects were funded by the CCI Collaborative Fund, which is generously supported by Arcadia.

Innovative approaches for protecting the future of Sierra Leone's Gola Forest – globally important for its biodiversity and its carbon reserves – are being developed by a collaboration of conservation agencies and Cambridge researchers.

Canopy commerce: forest conservation and poverty alleviation

Gola Forest, situated at the westernmost tip of a once extensive swathe of forest that stretched a thousand kilometres from Sierra Leone to Togo, is classified as a biodiversity hotspot of global significance. Its 71,000 hectares are home to over 330 species of bird, including the rare White-necked Picathartes and Rufous Fishing Owl, more than 500 species of butterfly, and a long list of threatened and endangered plants and animals.

The forest, which was recently designated a National Park, is recovering from a history of commercial logging and mining, and areas have also been cleared by local communities for agriculture. Without protection, logging and mining activities would undoubtedly be resumed and destroy what remains.

But the forest is not only important for its biodiversity. Like other forests, Gola is a vast carbon store, both in the biomass of the trees themselves and in its storage of carbon as dead organic matter beneath the forest floor.

For the past 20 years, the Royal Society for the Protection of Birds (RSPB) has been working with the Conservation Society of Sierra Leone and the Sierra Leone Government to protect the Gola Forest. Safeguarding its future in perpetuity is a priority, as Dr Jeremy Lindsell, Senior Conservation Scientist at RSPB explained: "Without the Gola Forest Programme, it's likely the forest would eventually be lost. Our goal is to find a mechanism by which richer countries can help one of the poorest



White-necked Picathartes, endemic to the Gola Forest

countries in the world protect its nature at the same time as improving the livelihoods of the local communities."

Now, innovative approaches to forest conservation and poverty alleviation are being pioneered by two projects made possible by the Cambridge Conservation Initiative (CCI). Each project is a unique collaboration between researchers, practitioners and policy makers.

Plant scientists Beccy Wilebore and Dr David Coomes, with CCI partner organisations RSPB and the United Nations Environment Programme World Conservation Monitoring Centre (UNEP-WCMC), are conducting research for a scheme to fund forest conservation through carbon credits. And Dr Andreas Kontoleon and Dr Maarten Voors from the Department of Land Economy,

together with RSPB, BirdLife International and the Universities of Wageningen and Chicago, are working with local villagers to establish how best to reward them for forest conservation.

Carbon credits for conservation

Current estimates suggest that around 12%–17% of global greenhouse gas emissions result from deforestation and forest degradation. A drive to reduce emissions from deforestation and forest degradation (REDD+) by incentivising countries to keep forests rather than clear them is currently being developed internationally by governments, conservation agencies, scientists and the private sector.

"Long-term funding for conservation of forests like Gola is difficult to secure, so

carbon markets offer one possible solution," explained Lindsell. "To do this, we must be able to demonstrate that the Gola Forest Programme is not only benefiting biodiversity, but that it is also reducing deforestation and securing the carbon stocks – essentially that our intervention makes a positive difference."

This is where the expertise of the plant scientists comes in. Wilebore, whose research is funded by the Natural Environment Research Council, is working with RSPB to determine how much carbon is in the forest and in the surrounding mosaic of land, which has been 'slashed and burned' for agriculture and is now regrowing as secondary forest.

"Once we know the baseline – the level of emissions we would expect from deforestation and forest degradation in the absence of the Gola Forest Programme – the impacts of the conservation programme on future carbon stores can be gauged," she explained. To calculate the baseline, she is gathering information from ground-based inventory plots, satellite imagery of land cover types and, soon, three-dimensional images of forest structure obtained by airborne remote-sensing devices. A rigorous system will be developed by the research partners to measure current forest carbon stocks and predict changes in forest carbon stocks in the future.

"An important aspect of the new methodologies will be to advise policy makers on the relative merits of different approaches for estimating how much carbon would have been lost if the forests had been left unprotected," added Coomes. "UNEP-WCMC will contribute greatly towards ensuring that lessons from the development of methods for Gola will influence the development of REDD+ policy at a critical point in time." Over the next year, the data will help the Gola Forest Programme assess how carbon trading can be used to protect the forest and at the same time cut global carbon emissions.

Assessing livelihood impacts

Agreements have been struck with forest-edge communities to limit activities such as farming and hunting in the new National Park. In return, substantial funds have been set aside by the Gola Forest Programme for livelihood improvement for these communities. The funds support such projects as the building of schools and latrines, as compensation for benefits that have been foregone.

Although it's widely acknowledged that, to be successful, conservation programmes must be coupled with poverty alleviation schemes, "there is scant hard scientific evidence on the impact of conservation policies on livelihoods, or on specific aspects of human behaviour that are related to conservation," explained Kontoleon. The project he leads aims to address this gap.

Pooling expertise from economics, anthropology and conservation science, the



Exposed tree trunks visible in the Gola Forest are the telltale sign of human activity in what might otherwise appear to be thick forest

team has carried out extremely detailed surveys of more than 2,800 households across 180 villages during the past two years. This has provided a 'pre-treatment' baseline recording all aspects of the villagers' economic and social lives.

With the support of the Gola Forest Programme, the team then tested the impacts of a series of different conservation–livelihood interventions using randomised field experiments with 'treated' and 'control' groups (within ethical experimental norms).

For example, in one study, they experimentally assessed ways to improve co-operative behaviour within communities, given that pro-social behaviour is known to be essential for the effectiveness of conservation programmes. In another study, they evaluated how effectively conservation funds intended for community projects were actually spent under different managed regimes. And they explored how social cohesion and support for conservation can be best advanced by comparing aid payments allocated to village chiefs versus funds allocated directly to individuals, or through a voucher-for-work scheme.

After a return visit for a follow-up survey, the researchers are now analysing the data, with results expected early in 2012. "All in all, the project will provide the first detailed formal policy evaluation of a major conservation programme," said Kontoleon. "The results should allow us to derive reliable inferences on the livelihood and behavioural impacts of conservation policies."

Predicting change

Over the next year, the two project teams will begin working more closely. Their combined data will help the researchers understand what drives changes in land use, and what effect this has on the environment and the impact of support programmes. Against a background of a rising world population and an increasing demand for food, studies such as these will prove vital for balancing

global pressures at the least cost to biodiversity.

The Gola Forest Programme might be regarded as something of a test case for how a large and dynamic biodiversity conservation project can be implemented sustainably in a developing country. "The stakes are high in terms of the biodiversity and carbon that is at jeopardy, the impacts on human welfare, and the conservation funds spent," said Kontoleon. "A vital ingredient for the success of the research projects in providing reliable assessments is the degree of collaboration, nurtured by CCI, between academia and conservation organisations, which cannot be taken lightly."



Dr David Coomes (left), Beccy Wilebore and Dr Jeremy Lindsell (Dr Andreas Kontoleon not shown)

For more information, please contact Dr Coomes (david.coomes@plantsci.cam.ac.uk) at the Department of Plant Sciences (www.plantsci.cam.ac.uk/) and Dr Kontoleon (ak219@cam.ac.uk) at the Department of Land Economy (www.landecon.cam.ac.uk/), or visit the Gola Forest Programme website (www.golarainforest.org/) and CCI website (www.conservation.cam.ac.uk/).

These projects were funded by the CCI Collaborative Fund, which is generously supported by Arcadia.

An innovative horizon-scanning exercise, which has just delivered its latest report, highlights emerging topics of relevance to the world's natural environment and the diversity of its species.

The crystal ball of conservation

Humanity faces a breadth of environmental challenges that will continue to put pressure on policy makers, industry and civil society groups to develop solutions, and on researchers to provide evidence. What if we could look ahead to predict the emerging issues at an early stage, enabling knowledge to accumulate in advance of crucial decision making?

For the past four years, just such a 'horizon-scanning' process has been undertaken in Cambridge by a group of experts from academia, conservation organisations and government. Led by conservation scientist Professor Bill Sutherland, the Miriam Rothschild Professor of Conservation Biology, the group aims to spot trends, novel technologies, new issues and even solutions that relate to biodiversity conservation. The idea is to identify serious potential conservation issues and opportunities before they turn into major challenges.

Take biofuel, for instance. Planting crops as a fuel source could help mitigate our dependency on fossil fuels. But when President George Bush announced the United States' commitment to biofuels in 2006, and the European Union followed suit, many of the ecological, climate-change and social impacts of an expansion in biofuels were



poorly known and, crucially, not prepared for. "What followed were some actions that arguably caused more damage than the burning of fossil fuels, such as the chopping down and draining of ancient peat-rich tropical swamp forests to make way for biofuel crops," explained Sutherland. "Once the issues were identified, there was then some acrimonious debate and calls for back-peddling of policies that could have been avoided if society had identified the merits and problems of biofuels earlier."

For the horizon-scanning exercise to be really useful, the group must identify emerging issues that are not well known but could have substantial impacts on the conservation of biological diversity. This year,

over 250 individuals contributed to the identification of a starting list of 80 issues that were deemed under-considered yet potentially important either for maintaining species or ecosystems or regions of global environmental interest. A 22-strong international panel, including horizon-scanning experts from across a wide range of institutions and agencies, then independently scored each issue to derive a shortlist of over 40 emerging issues of importance. It was these issues that were reviewed at a workshop in Cambridge in September 2011, where another round of voting resulted in a final line-up of 15 issues that have just been published in *Trends in Ecology and Evolution* (see panel).

“We can’t hope to spot all potential issues. But if some of the issues prove to be important, then identifying and publicising them early on will better prepare us for future environmental challenges.”

Global conservation issues for 2012

Fifteen potential threats and opportunities in climate, technology and human behaviour have been identified in a recently published horizon-scanning exercise.

The full list of 15 issues is as follows:

- Warming of the deep sea
- Mining in the deep ocean
- Methane venting from beneath the ocean floor
- Climate-driven colonisations in Antarctic waters
- Increases in pharmaceutical discharges as human populations age
- Sterile farming to increase food safety
- Transferring nitrogen-fixing ability to cereals
- Increased cultivation of perennial grains
- Rapid and low-cost genomic sequencing
- Electrochemical seawater desalination
- Rapid development and extensive application of graphene
- Nuclear batteries
- Effect of increased cement demand on karst forest and cave ecosystems
- In-stream hydrokinetic turbines
- Arctic tundra burning

The article, ‘A horizon scan of global conservation issues for 2012’, was published online in *Trends in Ecology and Evolution* on 30 November 2011.

Global conservation issues

Several of the issues identified by the horizon-scanning exercise relate to the deep oceans, which are rarely observable by the public and yet are strongly affected by changes in human activity. Deep-sea temperatures, which have been low and stable for millions of years, are known to be increasing. The report highlights concerns related to the warming seas, including the potential release of plumes of methane previously trapped beneath the sea bed, and the spread of predators, such as red king crabs, which normally live only in the colder parts of the ocean.

Also affecting the oceans are rich deposits of rare earth elements, such as yttrium used for electronics and as a source of green energy, which have been discovered in the deep-sea mud of the Pacific Ocean. The report recognises that increased deep-sea mining could become more frequent in the event of a global shortage of these precious minerals.

The horizon-scanning process also highlights areas that will grow in prominence over the coming years. For example, the experts have identified an increasing demand for two new technologies that may have as-yet-unknown environmental impacts – nuclear batteries and graphene. Nuclear batteries hold promise in providing a safe, cheap and almost endless supply of energy, particularly for remote communities that lack energy infrastructure. Graphene is the thinnest and strongest material ever detected and, given the magnitude of research in this

area, could be seen in products in the home within the next few years.

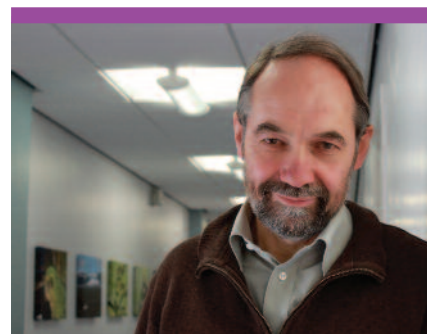
Human behaviour also comes under scrutiny. As a result of an ageing population, there has been an increased release of pharmaceuticals into the environment through waste water and sewage discharge, prompting concerns relating to the spread of antibiotic resistance through the ecosystem.

Evidence-based conservation

Horizon scanning is a key priority for the Cambridge Conservation Initiative (CCI), many of whose partner organisations are involved in the process that has created the latest report. Fitting with CCI’s philosophy, the exercise involves policy makers and practitioners at all stages of the discussion process.

Sutherland is a keen advocate of ‘evidence-based conservation’ and has created a free web resource (www.conservationevidence.com/) that helps busy practitioners base conservation decisions on hard evidence, without having to keep up with the research literature.

He believes that a forward-thinking shift in focus has an enormous role to play in conservation: “We can’t hope to spot all potential issues. But if some of the issues prove to be important, then identifying and publicising them early on will better prepare us for future environmental challenges. Our hope is that horizon scanning will foster research to examine the advantages and consequences of possible changes.”



Professor Bill Sutherland

For more information, please contact Professor Sutherland (w.sutherland@zoo.cam.ac.uk), the Miriam Rothschild Professor of Conservation Biology, at the Department of Zoology (www.zoo.cam.ac.uk/).

The latest horizon scan was funded by the Natural Environment Research Council, the Royal Society for the Protection of Birds and the European Centre for Environment and Human Health. Professor Sutherland is generously funded by Arcadia through the Miriam Rothschild Conservation Programme.

A new study reveals how the gathering together of conservation organisations in one location – a ‘conservation cluster’ – can work best to reap global rewards.



Conservation clusters: making the case

Silicon Valley, Bangalore, Shanghai. At one time or another, each of these locations, among others, has become home to a successful ‘business cluster’ of industries. Although the term was coined as recently as 1990, clustering of businesses in the same geographical locality has taken place for centuries, driving productivity, innovation and expertise.

A comparatively new phenomenon is the co-location of institutions whose goal is to protect and manage biodiversity worldwide. The difference is that whereas business clusters are built on inter-firm competition resulting in enhanced economic growth, conservation clusters are built on inter-organisation collaboration resulting in innovative solutions to a global threat.

A new study by Vena Kapoor, a student on the MPhil in Conservation Leadership Programme in the Department of Geography, has identified 17 conservation clusters currently in existence globally. Clustering brings advantages, as she explained: “Like their business counterparts, conservation clusters benefit from the physical proximity of similar organisations in terms of the potential for knowledge spill-over and a growing pool of skilled employees.”

Her study explores how conservation clusters function optimally, highlighting best practices and lessons learnt for current and future conservation clusters. “Probably the most important aspect for success is for a cluster to be based on a social network that initiates and facilitates a trusted collaboration,” she said. “Those clusters that began with an injection of funds but no underlying social network have been less successful.”

Cambridge is home to the largest conservation cluster in the world. Comprising eight conservation organisations, a conservation network and departments of the University, the cluster has been co-ordinated as the Cambridge Conservation

Initiative (CCI) since 2007, and is also a Strategic Initiative of the University.

“In Cambridge’s case, the network took the form of the Cambridge Conservation Forum (CCF),” explained Dr Mike Rands, Executive Director of CCI. “Out of CCF bubbled a series of programmes that people wanted to do together. Then came the process of co-ordinating these collaborative programmes and raising the funds to deliver them.”

A representative and democratic governance mechanism and a neutral facilitator to guide the collaboration were also identified as key features of successful clusters. The study concludes that ideally these features should take the form of a ‘cluster initiative’ that improves the collaborative potential of the cluster and raises independent funds for it. Although rare in conservation, cluster initiatives have become a popular feature in business, often with government support.

“Collaboration between organisations linked by a common cause has the potential to unleash synergies and spur innovation that can positively impact the world,” added Rands. “But even the best initiatives can be derailed. At this early stage in the creation of conservation clusters, it’s important to be aware of the challenges as well as the rewards.”

For a cluster to be successful, the advantages of being part of the collaboration must continue to outweigh the disadvantages, as Kapoor explained: “In the beginning, members get something from each other – they all learn about each other’s practices, research agendas and tools. But tension can develop when a member perceives a growing competitive overlap with another member, a feeling of dominance by a single or few members, or a lessening of their branding or niche position.”

“This is where a neutral facilitator can continually bring value,” said Dr Stelios Zygliopoulos, from the Cambridge Judge

Business School, who co-supervised the study with Dr Rands. “The purpose is to bring oil and water together – to forge links between different organisations. It’s through bringing together different kinds of people and organisations that innovation happens.”

Dr Rands agrees: “If there is a lesson that I’ve learned it’s to keep fostering the mixing of researchers and practitioners across disciplines. Only then can we demonstrate that together the members are able to do things that they could never have done on their own, and yet still progress their own individual organisation’s mandate and interests. This study makes a strong case for the global conservation community to harness the concept of clusters to deliver stronger and better conservation solutions for the world’s biodiversity and the natural capital it provides.”



Dr Mike Rands (left), Vena Kapoor and Dr Stelios Zygliopoulos

For more information, please contact Dr Rands (m.rands@jbs.cam.ac.uk) at CCI (www.conservation.cam.ac.uk/).

This research was funded through the MPhil in Conservation Leadership Programme by the MAVA Fondation pour la Nature and a scholarship from the Ravi Sankaran Inlaks Fellowship Programme.

Conservation scientists **Bruno Monteferri, Chris Sandbrook and Bill Adams** explore whether computer gaming is a new frontier for conservation.



Flower, an interactive video game, indirectly delivers a green message using the movement of a flower across a landscape

Games for nature

Deep in the rainforest, a monkey runs down a river, leaping from log to log over the mouths of the waiting crocs. So begins *Congo Jones and the Loggers of Doom*, a computer game that challenges players to work alongside local communities to protect the Congo rainforest from loggers. Offered free by a UK charity that supports indigenous peoples, the game is just one example of a new trend in the gaming industry towards games relevant for biodiversity conservation.

The emergence of such games is perhaps not surprising. Computer gaming is expanding fast. Worth \$29 billion worldwide in 2005, the industry reached \$40 billion by 2010. The underlying technology is advancing at an unbelievable pace, stretching media to unexpected places.

However, astonishing graphics are not the main factor driving people towards playing digital games. According to Tom Chatfield (author of *Fun Inc.*), "the games industry has discovered that the most successful games of all are those that come closest to real life, not in terms of ever more realistic sounds and images, but in terms of social interaction and interfaces with the human world." On both counts, conservation ticks the boxes.

Although debate has begun about the implications for the gaming industry of 'games going green', the risks and opportunities for nature conservation have as yet been little explored. Can games adequately explain the complex ecological, political and social basis of biodiversity loss? Will virtual nature start to outshine living nature in the eyes of a game-obsessed world? Or can games engage a generation who have already lost contact with wild nature?

For the past six months, we have been running a pilot project to address such questions, culminating in a recent workshop for conservation organisations and game

development companies, and funded by the Cambridge Conservation Initiative. Our goal is to promote a platform for potential collaboration and research on the use of games for nature conservation purposes.

But why should conservation organisations care about games for nature? Video games are an increasingly important social force. In the USA, 87% of the population play video games. Globally, half a billion people play online games for at least an hour a day. Games are also not the preserve of the homework-shy schoolchild: the average age of gamers is about 30.

Is this a good thing? Many commentators say it's not, pointing in particular to the violence of games like *Halo* or *Grand Theft Auto*. Others disagree. Jane McGonigal, author of *Reality is Broken: How games make us better and how they can change the world*, argues that video games are a powerful platform to solve global problems. Another commentator, Tom Bissell, in *Extra Lives: why video games matter*, says much the same, tracing the power of gaming narratives to engage the player in ways that literature, music, film and visual art cannot.

So if video games are taking over the worlds of leisure and social interaction, and forming the world that people – particularly younger people – live in, what implications does this have for traditional areas of social concern, such as the environment? There are a number of games about human use and abuse of nature, such as Red Redemption's *Fate of the World*. These form part of a growing field of 'serious games' with a social context and purpose: the antithesis perhaps of the classic 'post-apocalypse' warring worlds of popular imagination.

Moreover, conservation organisations have started using the underlying principles of games to make conservation initiatives more engaging for audiences. For instance, a number of games are being developed that require players to carry out activities in both

virtual and real worlds, creating new opportunities for nature conservation.

In the course of this pilot project and workshop, have we answered all our questions? Unsurprisingly, we have not. Did we conclude that they were important? Absolutely: gaming is a deadly serious industry whose business depends on the pleasure it gives its customers, but it also has a vital role to play in shaping the way decisions are made about human use of nature. As Bissell argues in *Extra Lives*, "we're going to change the world and entertain in a way that nothing else ever has." That's a promise no conservationist (and indeed no university) can afford to ignore.



Professor Bill Adams (left), Bruno Monteferri and Dr Chris Sandbrook

For more information, please contact Bruno Monteferri (brunomonteferri@gmail.com; www.gamesfornature.org/), Dr Sandbrook or Professor Adams, Moran Professor of Conservation and Development. Dr Sandbrook is funded by the MAVA Fondation pour la Nature.

A new study of tropical forests will provide a 50,000-year perspective on how animal biodiversity has changed, explored through an archaeological investigation of animal bones.



A lost world? How zooarchaeology can inform biodiversity conservation

As dawn breaks, a Cantor's Roundleaf bat flies through the lush rainforest canopy searching out its colony. Its home is the Great Cave of Niah, Sarawak, in northern Borneo, where it accompanies tens of thousands of other bats, careening through the cave after a night's work hunting insects. It's a scene that has probably been replicated daily for tens of thousands of years.

Evidence for the longevity of bat colonisation of the cave has been revealed through analysis of some 12,000 bat bones, as well as 1,400 bird bones, uncovered by archaeologists digging in Hell Trench at the West Mouth of the cave, and examined and dated by Cambridge zooarchaeologist Dr Chris Stimpson. His recently completed study, which was funded by the Natural Environment Research Council, suggests that bats have been living there for 50,000 years.

The forest surrounding the Great Cave of Niah once blanketed the entire state of Sarawak, but today only pockets remain such as the Niah National Park, where the cave is located. Conservation efforts here and elsewhere in the world are faced with

the challenge of how best to manage and conserve what is left of some of the most biologically diverse and complex habitats on Earth.

Stimpson, along with other zooarchaeologists around the world, believes he has something new to offer the debate: "Conservation efforts draw on relatively recent ecological evidence. To formulate effective priorities for biological conservation, zooarchaeology, or the study of ancient animal bones, can provide a remarkably long-range perspective. It can tell us something about the nature of animal communities before humans intensively modified their habitats, as well as provide a deeper understanding of the role that humans have played in structuring tropical forests across millennia."

Tall, moisture-loving, closed-canopy forests form a band around the equator and have been described as of "disproportional importance" in driving patterns in global biodiversity and the global carbon cycle. The ambitious study begun by Stimpson will measure changes in animal communities in tropical forests over 50,000 years and across three continents.

The bare bones

The idea behind the new study grew out of Stimpson's PhD research at the Great Cave as part of a major research project begun in 2000 under the leadership of Graeme Barker, Disney Professor of Archaeology and Director of the McDonald Institute for Archaeological Research in Cambridge. The long-term investigation, which was funded principally by the Arts and Humanities Research Council, involved a team of 40 archaeologists and environmental scientists from a dozen universities. The team found astonishing evidence for sophisticated methods used by early Modern Humans to exploit the rainforest as far back as 45,000 years ago, from specialist hunting techniques to the neutralisation of poisons.

Famously, the oldest reliably dated Modern Human fossil in Southeast Asia yet recorded, known as 'Deep Skull', had previously been discovered within the cave in the 1950s by Tom and Barbara Harrisson. As a result of Barker's research, its age was confirmed as 37,000 years old.

"There had been some debate as to whether the rainforests were a major barrier



DR CHRIS STIMPSON

An analysis of 12,000 ancient bat bones is being combined with similar archaeological analyses from around the world to provide a long-term assessment of changing biodiversity

West Mouth of the Great Cave of Niah, Sarawak



DR CHRIS STIMPSON

“I’m trying to knit biological conservation and archaeology together.”

to the dispersal of modern humans because of the difficulties of foraging in an environment where food is widely dispersed and ephemeral, and sometimes inaccessible in the canopy. But the findings in the Great Cave showed that they weren’t flailing around. They coped well, were thinking ahead and adapting to change,” said Stimpson.

Tropical forests such as the Niah National Park are often regarded as the world’s last ‘virgin landscapes’. Yet this runs contrary to Stimpson’s and others’ findings, as he explained: “These communities may have been subject to exploitation and modification by humans for thousands of years. Essentially, what we regard as ‘pristine’ ecosystems are in fact ‘degraded’ ecosystems. Zooarchaeology can help those involved in conservation efforts to understand how ecologically representative remnant stands of forest are.”

After painstakingly analysing the vast number of animal bones found in the cave, Stimpson discovered that people were hunting hornbills at least 19,000 years ago and eating cave-dwelling fruit bats 42,000 years ago. He was able to identify bones from

four species of hornbill, although only a single species remains in the forest today.

Using the distal part of the humerus bone (close to the elbow) as a taxonomic marker to differentiate between species of bat, Stimpson found that a colony of wrinkle-lipped bats, which may have numbered as many as three million individuals at its peak, had disappeared by the 17th century: “This may be because the colony was disturbed when people began to visit the cave regularly to collect the nests of cave swiftlets, whose edible nests were much prized as the main ingredient of bird’s nest soup,” he said.

By contrast, he found evidence to suggest the persistence of the Strategy I bats, a guild of bats that need closed-canopy forest to hunt. “If you lose the closed-canopy forest, then you lose this group of bats,” he explained. “This finding presents a robust case for the existence of closed-canopy rainforest for at least 50,000 years, putting starkly into perspective the fact that recent forest felling has reduced the forest by two thirds in the past 40 years.”

Looking for ‘lost worlds’

“Attempts to contextualise and quantify the extent of human impact on the biodiversity and resilience of the tropical forest are hampered by the lack of studies that consider tropical forests from millennial timescales,” Stimpson said. “Yet, such studies can provide benchmarks far deeper in time than ecological snapshots, which rarely approach 50 years in duration.”

Although the title of the new research project, ‘A lost world? Zooarchaeology and biological conservation in the tropical forest biome’, tips its hat to Sir Arthur Conan Doyle’s tale of an expedition to a South American plateau where prehistoric animals still survive, it does so because it considers study sites at times before the recent intensive modification of habitats by humans. In other words, tropical forest communities that might now be considered ‘lost worlds’.

“I’m interested in what role humans have played as active predators in structuring the animal communities of tropical forest habitats and what implications this has for the animal communities we see today,” explained Stimpson, whose new research is funded by the McDonald Institute for Archaeological Research.

To do this, he is pulling together published zooarchaeological datasets from 26 studies at archaeological sites in Central and South America, Central Africa and Southeast Asia, with a view to eventually increasing this to 40 datasets. Each dataset represents a faunal inventory listing all of the different animal groups that are evident from the thousands of bones retrieved in the course of excavation. He will then compare this with the fauna that exist in the region today.

Because the project is so broad in its spatial and temporal coverage, it will allow Stimpson to characterise the direct and indirect effects of human hunting behaviour in geographical regions over millennia. He will be able to ask whether trends exist in the spectrum of targeted animals and what ecological role these animals play in tropical forests.

As his studies progress, Stimpson will work closely with conservation scientists in Cambridge: “I’m trying to knit biological conservation and archaeology together.” The results, he believes, will provide a powerful tool to improve current understanding of ecosystem change in response to anthropogenic pressures. Crucially, the long-term benchmark data produced by the project will be of direct relevance to conservation initiatives working in the tropical forest biome; his aim, as he explained, is to ask: “How can we utilise these data in the best possible way to inform conservation priorities for protection?”



Dr Chris Stimpson

For more information, please contact Dr Stimpson (cs474@cam.ac.uk) at the McDonald Institute for Archaeological Research (www.mcdonald.cam.ac.uk/).

Over the past few years, the genre of 'nature writing' has seen a new sense of urgency, fostered by a growing awareness of a natural world under pressure. Dr Robert Macfarlane, from the Faculty of English, believes that writers have played, and continue to play, a central role in conservation by engaging our hearts and our minds.



Landscape, literature, life

Last November a new word – “scratling” – emerged briefly into the world. The journalist Mark Cocker, a regular contributor to *The Guardian's* Country Diary column, coined it to describe the sound made by starlings settling down to roost overnight in his roof in rural Norfolk. Cocker talks about the wild “excess of energy” in the arching movements of a flock of starlings and the “grey, clamped-down stillness” of November. In focusing on his own delight in the ebb and flow of a flock of birds in the darkening sky, he expresses something universal about our inmost connectedness with nature.

Country Diary has long been a tiny island of nature writing, taking readers away from their homes, trains and offices to the wilder and less-trammelled spaces of moor and mountain, coombe and common, wilderness and wasteland. There was even a sense that those who wrote for this slot and others like it were an endangered species, donning their boots to tramp back into a landscape that no longer held any relevance for most of us.

Not any more. Prompted largely by a growing awareness of a world under threat, a steady resurgence in forms of ‘new nature writing’ has been seen during the past decade. The human population is expanding and limited natural resources are under pressure; scientists recording the numbers and diversity of flora and fauna show us that precious habitats are being lost and vulnerable species driven to extinction. Nature writing is succoured by accurate description, while at the same time draws attention to large-scale environmental crises and local losses. It is driven by a sense of purpose that gives it an important role within modern conservation, informing us in

ways that are both factual and emotionally affecting.

How literature shapes, and is shaped by, our awareness of nature – and how this awareness, or the lack of it, intersects with our behaviour – is central to the research and writing of Cambridge academic Dr Robert Macfarlane, who has made a substantial contribution to placing nature writing centre stage of recent environmental discussions in this country. His work explores the traditions of British, Irish and North American literatures that deal with nature and its relationship with humankind – from the late 18th century through to the present day. His research is located within the lively interdisciplinary field known as ‘cultural environmentalism’, which considers the ways in which not only literature but also sculpture, dance, film and music might influence ecological awareness and environmental activism.

“Literature is just one of the cultural forms that shape our place-consciousness, and that carry out particular kinds of thinking about how we fit within the biosphere,” he explained. “The sculptures of Richard Long and Andy Goldsworthy, and the scripts of the latest blue-chip David Attenborough nature documentaries also bear upon the ways we treat that web of species, interrelations, co-dependencies and chemicals that we have relatively recently come to know by the group-noun ‘environment.’”

Increasing specialism within the conventional British education system has often set science and literature at opposite ends of a spectrum. In his teaching and research, and as the author of two highly acclaimed books of nature/travel writing (*Mountains of the Mind*, 2003; *The Wild Places*,

2007; and a third, *The Old Ways*, to be published in 2012), Macfarlane is keen to reconcile the two broad areas. Talking about his respect for conservationists, he quotes the poet W.H. Auden: “When I find myself in the company of scientists, I feel like a shabby curate who has strayed by mistake into a drawing-room full of dukes.” He is eager, however, to highlight the role that literature has played in the history of environmentalism.

“Whenever I ask professional conservationists what first inspired them to get involved in the protection of the environment, they invariably mention either a book or a place,” he said. “The experiences of reading, or the physical effects of being in the landscape – of being exposed to the elements and feeling the land underfoot or under-hand – have proved profoundly influential for so many environmental policy makers and researchers. Nature writing has, in the past, been cartooned variously as reactionary ruralist or as sentimentalist. But, in many ways, and for many people, it’s been decisively life-shaping.”

Our everyday discourse is rich with metaphors and similes taken from earth, sea and sky – from the subtext of individual sounds in words to the grandest panoramas of desert and wilderness that have become symbols of states of mind. We live



ROSAMUND MACFARLANE

Crummock Water, Cumbria

“Whenever I ask professional conservationists what first inspired them to get involved in the protection of the environment, they invariably mention either a book or a place.”

Next year an opera with music by the jazz double-bassist Arnie Somogyi and with a libretto by Macfarlane will be performed on Orford Ness, a vast offshore shingle spit on the Suffolk coast that is both ecologically and historically unique. The opera has been part-commissioned by the National Trust, which owns the Ness and is keen to explore artistic responses to this extraordinary landscape. For Macfarlane, it’s an opportunity to bring culture and environment together in a thoroughly unacademic fashion, and to create, with Somogyi, an artistic form that will be responsive to the character of the landscape. What Macfarlane and Somogyi find most fascinating and suggestive about the terrain is how the lean and tapering shape of Orford Ness is constantly shifted and reformed by time and tide – a scaled-up, slowed-down, stone-and-water version of the wild wheeling arc of starlings in the sky.

**Dr Robert Macfarlane**

For more information, please contact Dr Macfarlane at the Faculty of English (www.english.cam.ac.uk/).

increasingly in cities, yet some of our greatest literature draws on nature not just as backdrop but also as active agent, shaping character, behaviour and morality. The classics of children’s literature, in particular, use wetlands and waterways, farm and forest as the settings and atmospheres for powerful characters and narratives.

Yet what we love, and what feeds us both literally and metaphorically, we also destroy. It is in drawing attention to the vulnerability of the natural world to greedy humanity that nature writers can play a role, believes Macfarlane: “Wendell Berry, the American farmer and essayist who is too little known in America, let alone in this country, once wrote that environmentally we require not ‘the piecemeal technological solutions that our society now offers, but ... a change of cultural (and economic) values that will encourage in the whole population the necessary respect, restraint, and care.’ I’m interested in how literature might have urged, or at least have tried to urge, such changes.”

“Every now and then,” he continued, “the imaginary forms of literature feed back into the lived world with startling consequence. They assume real-world agency in ways that exceed the cliché of ‘life imitating art’. In terms of environmental history, I think of John Muir, who took himself off to become a shepherd in the Sierra Nevada and whose

essays became crucial in determining the national-parks policy of Theodore Roosevelt. Or I think of the thunderclap publication of Rachel Carson’s *Silent Spring* (1962), which led to the banning of DDT in the US and arguably stimulated the creation in 1970 of the State Environmental Protection Agency. And then there’s the vast and as-yet-unmapped influence of Cormac McCarthy’s *The Road* (2006), a novel that chills its readers to their cores, and which the campaigner George Monbiot described as the most important environmental book ever written.” Macfarlane has been working hard to bring lost or neglected works from the nature writing tradition back to light, and to introduce them to new generations of readers. He has written essays to accompany reissues of books by W.H. Hudson, Edward Thomas, Nan Shepherd, J.A. Baker and John Stewart Collis, among others. Next year, HarperCollins will reissue works by Jacquetta Hawkes (*A Land*), Richard Jefferies (*Nature Near London*) and Hudson (*Adventures Among Birds*); all three will carry introductions by Macfarlane, who added: “Over the past five or six years I’ve become addicted to digging into the ‘lost decades’ of 20th-century British nature/topographic writing. I feel passionate about championing writing which I feel might change its readers’ relationship with nature.”

An epic new history of the final 300 years of Germany's first Reich reveals how the period gave birth to modern German identity and principles that still underpin its attempts to lead Europe today.

Kaiser, Reich and the making of modern Germany

Map of the Holy Roman Empire 1492–1618



A decade in the making, *Germany and the Holy Roman Empire (1493–1806)*, by the University of Cambridge historian Dr Joachim Whaley, is the most comprehensive survey of Germany's early modern history ever undertaken, the first book of its kind since the 1950s, and one of the most substantial works of historical scholarship published in the UK in 2011.

The two-volume study tells the story of more than 300 principalities and about 1,500 other minor territories. Together, these made up the later Holy Roman Empire, which covered much of northern and central Europe and constituted Germany's original Reich. Whaley believes that their story challenges much of what we think we know about Germany and its people today. With Europe in crisis and many nations looking to Germany for leadership, he argues that the period reveals a deeper history of political co-operation and consensus, which is usually overlooked because of Germany's recent, often darker past. Today, the very word 'Reich', which has associations with the disastrous Third Reich, has become taboo. The first Reich was very different.

Historians themselves have also neglected the last three centuries of the Holy Roman Empire. Typically, the period has been portrayed as one of decline, in which the Empire fragmented into warring territories, was split by the Catholic-Protestant divide of the Reformation, was ravaged by the Thirty Years War, and

eventually became meaningless. Even some well-respected histories of Germany give its final decades only a handful of pages. After 10 years researching and writing the book, Whaley argues that it is time to look again.

State of the nation

Rather than being a weak, dysfunctional precursor of the strong Germany that emerged in the 19th century, the latter-day Holy Roman Empire was a successful political entity in itself, the new study suggests.

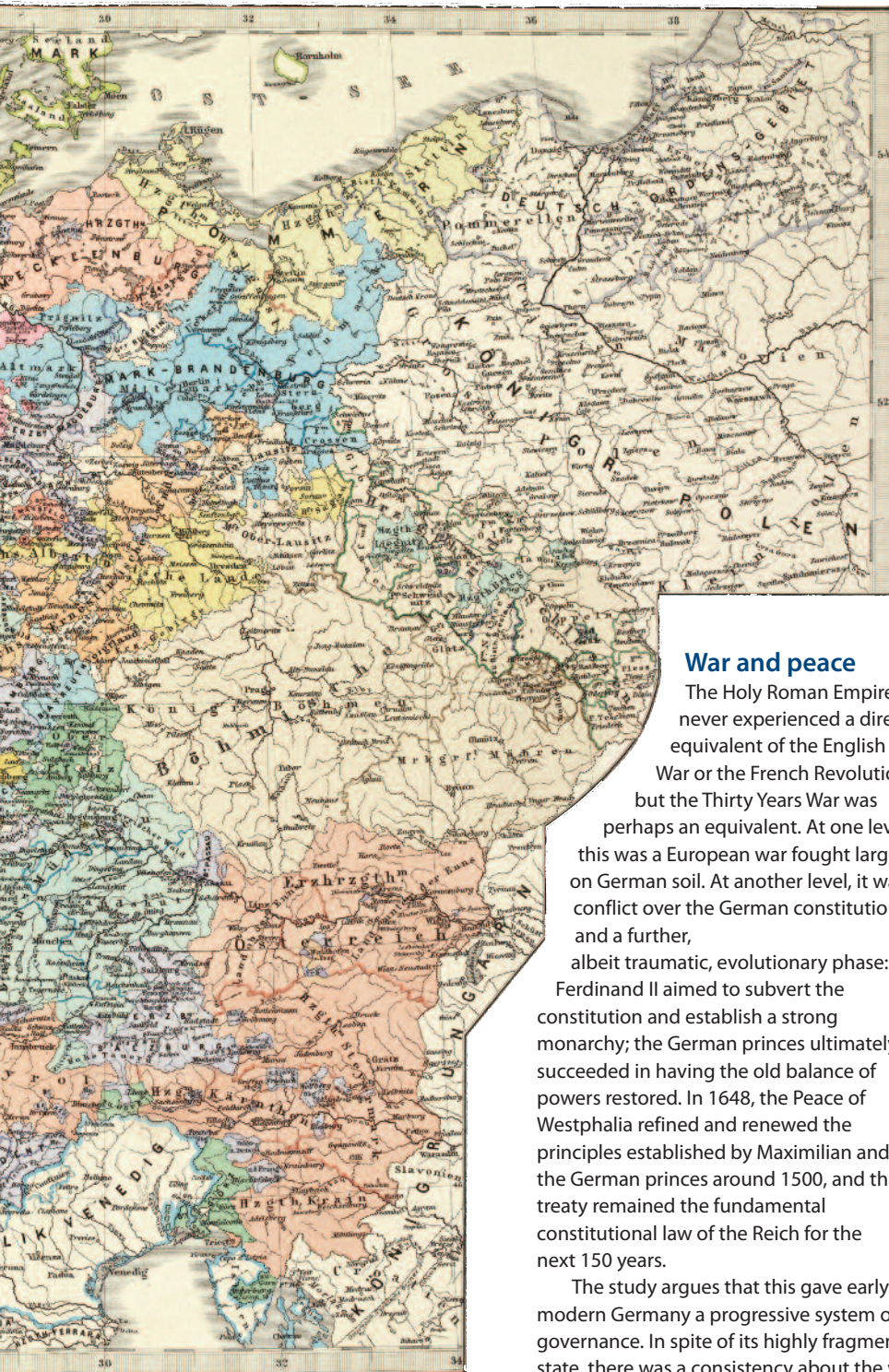
What we struggle with, he believes, is that its model was very different to our own idea of what a 'state' should be. In an era before nations, the Empire was a 'federative state' – made up of territories with interlocking identities. People saw themselves as both local and German, but there was no Imperial capital and 'Germany' comprised territories that today are part of France, Belgium, Poland, the Czech Republic and Austria, as well as the Federal Republic of Germany. While this political system may sound alien now, the book argues that by and large it worked.

"The history of German-speaking Europe in this period has been seen as the history of localities and territories, but it is also the history of the union of those entities and their survival," said Whaley. "Usually historians see this time as one of division in which the Empire failed to function as a nation state. What we forget is that for 300 years, it also held the German-speaking

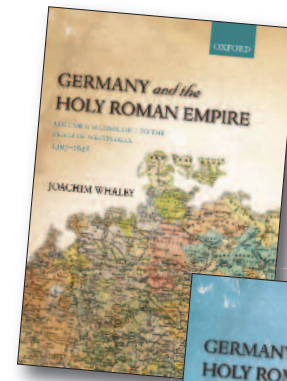
territories together as a legal and cultural community, in spite of numerous changes and external threats."

This community, the study suggests, laid much of the groundwork for German identity today. It began in the 1490s, when the Emperor Maximilian I and the German princes and cities carved out a two-tier system of government based on the concept of *Kaiser und Reich*. At one level, the Emperor provided governance in negotiation with the princes through the diet, the Reichstag. At the same time, however, all of the territories essentially governed themselves.

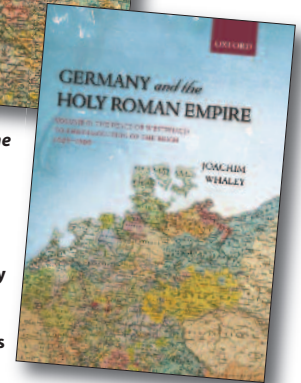
Although subject to their immediate ruler, people were also vassals of the



DR JOACHIM WHALEY



Germany and the Holy Roman Empire (1493-1806), Volume I and II, (2011) by Dr Joachim Whaley is published by Oxford University Press



War and peace

The Holy Roman Empire never experienced a direct equivalent of the English Civil War or the French Revolution, but the Thirty Years War was perhaps an equivalent. At one level, this was a European war fought largely on German soil. At another level, it was a conflict over the German constitution and a further, albeit traumatic, evolutionary phase: Ferdinand II aimed to subvert the constitution and establish a strong monarchy; the German princes ultimately succeeded in having the old balance of powers restored. In 1648, the Peace of Westphalia refined and renewed the principles established by Maximilian and the German princes around 1500, and this treaty remained the fundamental constitutional law of the Reich for the next 150 years.

The study argues that this gave early modern Germany a progressive system of governance. In spite of its highly fragmented state, there was a consistency about the way the different territories dealt with issues like judicial reform, welfare or education. As a result, the community constantly evolved a picture of itself as German: "There was a clear sense of the difference between the extensive rights and liberties they enjoyed as subjects of the Empire compared with, say, the subjects of the King of France," explained Whaley.

In times of war, the Emperor was still therefore able to raise an army that had the patriotic fervour needed to defend the Empire's borders. Critically, however, German identity became associated with the principles of the federative state – the protection and preservation of local rights, and unity in diversity. It failed only when it came under overwhelming military pressure from France after 1792 and was dissolved at Napoleon's insistence in 1806.

Future of Europe

Whaley's analysis stops short of claiming that the later Holy Roman Empire was the forerunner of a modern federal Europe. He does, however, suggest that it helps to explain how Germany perceives Europe, and why Germans find the notion of a united Europe more palatable than, for example, the British do.

"There is a history here of co-operation, consensus and compromise in German politics which is rarely acknowledged," he said. "For Germans, there is a federal mentality and habit that is deeply ingrained. This expects to deal with things by compromise and works slowly to broker deals and find ways to move forwards. Understanding the history of the Reich cannot help us to construct a blueprint for the future of Europe, but it can help us understand how Germany and Europe have become what they are today."

Emperor and could appeal to the laws of the Reich as a greater authority. While this led to some periods of instability and even war, Whaley argues that overall it created a political climate of negotiation, consensus and co-operation, and the recognition that each sub-region of the Empire had certain freedoms.

The result was a 300-year period of evolution. Maximilian's changes were just the first of different phases of reform which usually emerged because of religious differences, economic problems, social unrest or wars. Each time, the two-tier system adapted to accommodate the hundreds of territories it contained.

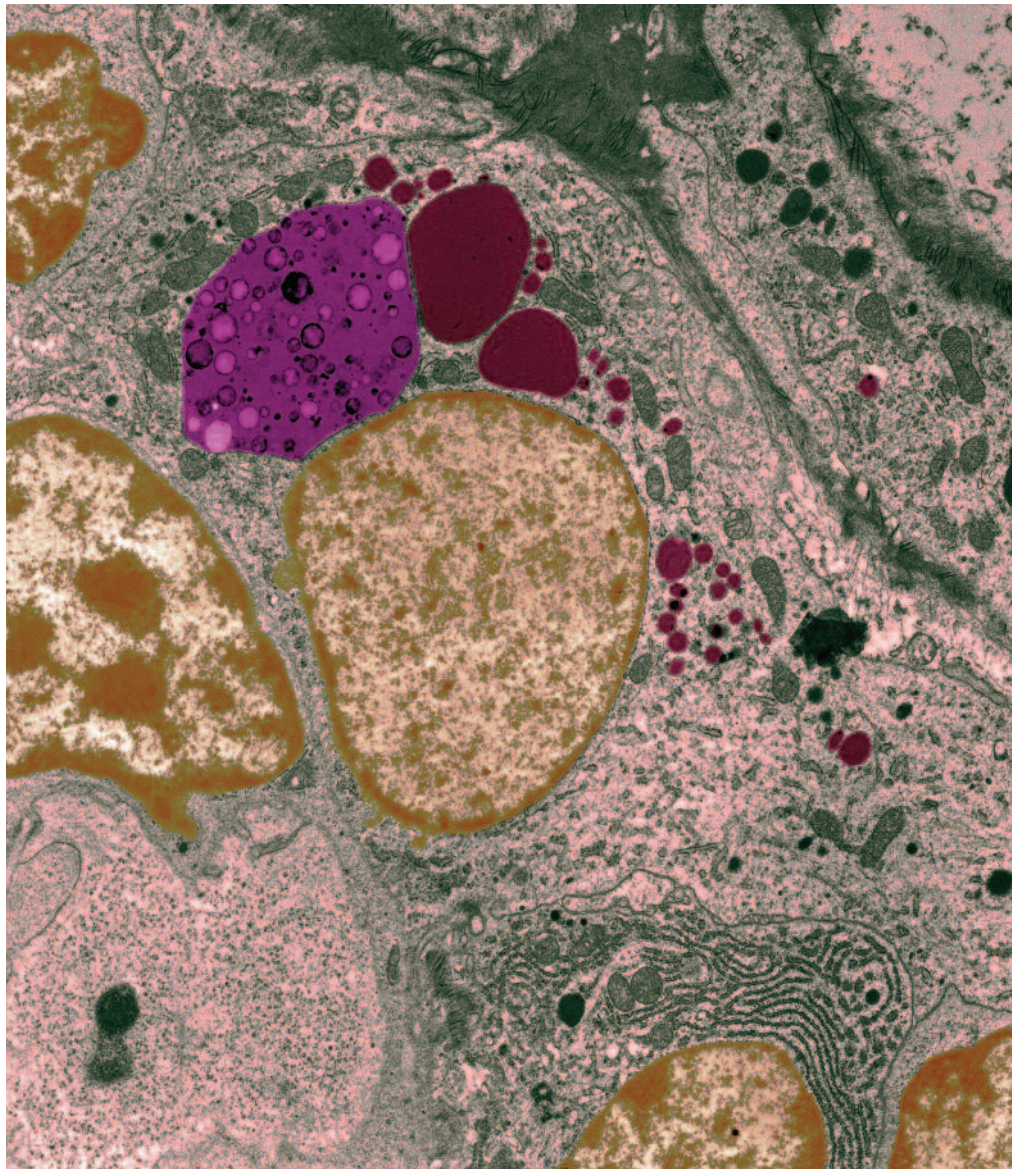


Dr Joachim Whaley

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New discoveries by Cambridge scientists about a molecular waste-disposal process that 'eats' bacteria are influencing the clinical management of cystic fibrosis, and could be the basis of innovative new treatments to fight off bacteria.

Molecular sacs of cell debris (pink) are delivered to the lysosome (dark red), where the contents are degraded and recycled



Autophagy: when 'self-eating' is good for you

Broken pieces of internal structures, damaged organelles and harmful clumps of proteins are all examples of the molecular detritus that builds up continuously in our cells. Fortunately, we are equipped with an intracellular process called autophagy (literally 'self-eating') that gathers up the debris, wraps it in a double membrane and delivers it to an intracellular sac called the lysosome. Here, the material is ingested, digested and recycled, ready to be used again.

Recent work has suggested that autophagy may also be important in killing intracellular bacteria that are able to escape the normal processes that control infection within cells. Autophagy appears to be critical in controlling infections of *Mycobacterium tuberculosis* (MTB) and related species called non-tuberculous mycobacteria (NTM), which are able to block degradation by lysosomes and thereby replicate within cells.

Researchers working at the University's Cambridge Institute for Medical Research

(CIMR) and Papworth Hospital have noticed that patients with chronic lung diseases such as cystic fibrosis (CF) are becoming increasingly infected with a highly pathogenic, multi-drug-resistant (MDR) NTM called *Mycobacterium abscessus*. Their research, published recently in the *Journal of Clinical Investigation*, suggests that *M. abscessus* infection may be linked to long-term use of azithromycin, an antibiotic with anti-inflammatory properties. They propose that azithromycin blocks autophagy in a type of white blood cell called the macrophage, effectively tipping the balance in favour of the *Mycobacterium* surviving in the cell.

It's an ominous outcome for patients, as lead researcher Dr Andres Floto explained: "Developing an infection with *Mycobacterium abscessus* is a big deal for patients with CF. It's resistant to virtually all antibiotics, is very hard to treat, can accelerate lung damage and may rule out future lung transplantation. While the benefits of long-term azithromycin therapy in

CF are clear, our data suggest that there may also be a downside to watch out for."

He added: "Recent studies showing the benefit of azithromycin therapy in asthma and smoking-related chronic obstructive pulmonary disease (COPD) will no doubt increase the numbers of patients on long-term azithromycin therapy. Physicians will need to be aware of the potential for harm with this treatment, and carefully monitor patients for mycobacterial disease".

'Forced stoppage' of the cleaning crew

Floto is a Wellcome Trust Senior Clinical Fellow in the Department of Medicine and Principal Investigator in the CIMR. He is also Director of Research at the Cambridge Centre for Lung Infection at Papworth Hospital. The Centre cares for over 260 adults with CF and almost 2,000 patients with recurrent or difficult lung infections.

"We'd been struck by the rising rates of *M. abscessus* infection in CF patients in centres around the world and wondered whether it could be connected to an increased use of long-term azithromycin," explained Floto. "Azithromycin is a broad-spectrum antibiotic which paradoxically is used to treat some mycobacterial infections. In patients with CF and, more recently, other inflammatory lung diseases such as asthma and COPD, it's being prescribed as a long-term anti-inflammatory therapy."

The association between azithromycin use and *M. abscessus* infection was first suggested when Floto and colleagues carried out an epidemiological study of adult patients with CF at Papworth Hospital and found that those patients with NTM infection were much more likely to be taking long-term azithromycin. When they looked at cells in culture, they discovered that the antibiotic impaired autophagy, effectively causing a 'forced stoppage' of the waste-recycling unit and preventing cells from clearing infecting mycobacteria. Moreover, azithromycin had a profound effect on *M. abscessus* infection of a mouse model; whereas untreated mice were able to clear the infection rapidly, those given the drug developed persistent lung infection.

Exploiting autophagy

The interactions of mycobacteria with immune cells are extremely complex and poorly understood. In a paper published in 2006 in *Science*, Floto together with Professor Paul Lehner at the CIMR began to define how immune cells respond to specific proteins from mycobacteria which then control the immune response. Subsequent work has suggested that the ability of macrophages to kill mycobacteria can be enhanced through a number of pathways, including autophagy.

Working with Professor David Rubinsztein at the CIMR, who has been interested in enhancing autophagy to clear the build-up of damaging clumps of proteins in neurodegenerative diseases, Floto has begun to study whether autophagy might be

Papworth Hospital and a new Heart and Lung Research Institute

Papworth Hospital, the UK's largest specialist cardiothoracic hospital and main heart and lung transplant centre, will be moving to a new location on the Cambridge Biomedical Campus to facilitate closer links with the University's School of Clinical Medicine and Addenbrooke's Hospital. Construction of the new 300-bed facility, expected to be complete by late 2015, also offers a unique opportunity for the construction of a new Heart and Lung Research Institute, which is to be built adjacent to, and integrated with, the new hospital. Together, the University and Papworth Hospital aim to create a world-class environment for heart and lung research leading to improved care for future patients.

For more information, please visit www.papworthhospital.nhs.uk/content.php?/about/new_papworth_hospital/

exploited therapeutically to treat multi-drug-resistant tuberculosis (MDR-TB), for which there is an urgent need to find new treatments. In 2008, the World Health Organization estimated that of the 9.4 million new TB cases 440,000 were MDR-TB. "It's a massive challenge", explained Floto, "We believe that stimulating autophagy to kill TB will bypass the problem of multi-drug resistance and may lead to potential new treatments for MDR-TB."

Meanwhile, Floto's work on azithromycin has already begun to influence clinical practice in a number of major CF centres in the UK. Although at pains to stress that a larger, prospective multi-centre study is needed before universal guidance can be given for the management of patients on chronic azithromycin therapy, Floto explained how the Cambridge Centre for Lung Infection has adopted a policy that is already proving successful: "We give patients who are not doing as well as we'd expect a holiday off the medication for a month while we screen carefully for NTM. When we do this, we often find a mycobacterial infection brewing in the lungs and can treat it immediately, instead of allowing the infection to take hold covertly without being detected."

Floto's research exemplifies the importance of a seamless link between fundamental research and clinical translation, and will benefit still further from the planned move of Papworth Hospital to the Cambridge Biomedical Campus (see panel). "Papworth has a unique group of patients and an international reputation for the treatment of patients with difficult lung infections," he explained. "Forging greater links between Papworth and the University will inevitably promote research into a number of clinically important areas and smooth the route from bench to bedside, and back again."

The antibiotic impaired autophagy, effectively causing a 'forced stoppage' of the waste-recycling unit and preventing cells from clearing infecting mycobacteria.



Dr Andres Floto

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Objects of devotion

In this 16th-century votive offering, the Viadana family prays to St Nicholas to save them from an earthquake

Why did Renaissance shoppers fill their baskets with rosaries, crucifixes, Christ-dolls and devotional paintings? A new study by historian Dr Mary Laven investigates the significance of Catholic clutter, as she explains.

An earthquake ravages a small town in central Italy. Catastrophic fissures rip through the buildings; desperate cries can be heard from those whose houses are collapsing; others try to attract attention by standing on rooftops and waving their hands but to no avail. Only one home stands firm while the buildings all around it crumble to the ground. Here, the Viadana family kneels in quiet prayer; husband, wife and four sons, all neatly attired and strikingly tranquil amid the chaos, appeal to their local saint, Nicholas of Tolentino.

This compelling image is preserved among the remarkable collection of *ex votos* at Tolentino, in the Marche region of central Italy: nearly 400 painted wooden boards, dating from the 15th to the 19th centuries, usually about a foot long and orientated horizontally, purchased or commissioned by those who had been granted a miracle thanks to the intervention of St Nicholas.

Ex voto means 'in fulfilment of a vow' and the idea was that when one prayed to the Virgin Mary or to the saints for a miracle one would promise to leave an offering in return for a favour granted. This is why, in Italy and

in other Catholic countries, shrines are sometimes bursting with objects and pictures like this one, each recording the miraculous activities of God's busiest saints.

I have been drawn to thinking about *ex votos* as part of my project on 'Objects of Devotion: The Material Culture of Italian Renaissance Piety, 1400–1600' funded by a Leverhulme Trust Major Research Fellowship. My research reacts against the common misconception of the Renaissance as a secular age, characterised by luxury, individualism, worldliness and scepticism. By focusing instead on the widespread 'consumption' of religious objects, I will cast light on the vibrant piety that shaped Renaissance lives. Through rosaries, crucifixes, Christ-dolls, statuettes, religious jewellery, devotional books and paintings, pilgrim souvenirs, and even instruments of self-mortification (the hair shirts or flails with which people in this period sometimes tested their faith), I aim to show that Renaissance shoppers filled their baskets with items that testified to a profound piety. But I shall also be asking why Catholic culture was defined by such a clutter of objects.



A gentleman is healed of a gunshot wound, 1523 (left); a couple give thanks for the recovery of their son, 1516 (centre); parents thank St Nicholas for saving their baby daughter after she falls from a balcony (right); all images courtesy of the Museo di San Nicola in Tolentino

The man who avoided Marys

Although focused on objects, my research will often be pursued via texts. Inventories and account books are the best means of informing us about patterns of expenditure in the Renaissance; trials carried out by the Inquisition can tell us about the uses and abuses of religious artefacts; meanwhile, the printed genre of the 'miracle book' provides essential context for understanding *ex votos*. During the first century or so of print, books that related the miracles accomplished by a particular saint were bestsellers. And when you come to read them, you can see why. Their dramatic recounting of some potentially horrific incident followed by a pious conclusion makes for a highly satisfying read.

Among my favourite stories is that of a lascivious and promiscuous man who nevertheless drew the line at having sex with any woman called Mary (an act which he considered profoundly blasphemous). Seeing an opportunity, the devil instigated a tryst between our hero and a woman who turned out to be named Maria. Fortunately, before the dreadful deed was committed, the man discovered the truth, and such was his remorse that he was saved from mortal sin by immediate death. That he then went straight to heaven, thanks to the intervention of the Virgin Mary, was a miracle indeed, even if it's hard from a modern perspective to see that as a happy ending.

Other stories chart the aversion of disasters involving children – narratives with which anxious parents today can easily identify. We learn of the miraculous rescue of a girl who falls from the roof of her home where she has been sunning herself, and of the baby who incurs 'monstrous' injuries to the face and blindness in one eye after her nurse allows her to tumble into the hearth. One particularly graphic tale from a Florentine miracle book is of a boy who nearly suffocates when he becomes submerged in excrement after hiding from his mother in the latrine. He is pulled out unharmed, and miraculously fragrant, by the Virgin Mary herself.

Familiar, yet unfamiliar

Miracle books also shed light on the many different kinds of *ex votos* that were commissioned: not just painted representations of the miracle granted, but a whole range of three-dimensional objects, including wax items that have rarely survived. Most typical are the anatomical models: a pair of wax eyes or ears to record the recovery of a person's sight or hearing, or a wax foot paid for by the mother whose little boy had been healed of a bad toe. The rich commissioned the same objects in silver. More humble folk might invest in candles identical in length to children that had been healed. Others hung up their crutches as a memento of their cure. Similar practices go back to antiquity and continue today at the great Catholic healing shrines such as Lourdes in France and Loreto in Italy.

As a historian therefore I'm left with a quandary. To what extent is the instinct to appeal for help from a saint or a divinity, or to make a public expression of gratitude for a calamity averted, a human constant?

To return to the *ex voto* commissioned by the Viadana family: at one level, the scene is all too familiar. Today, earthquakes, floods, tsunamis, terrorist attacks and bombings continue to cause cities to crumble. And yet the appearance in the painting of a tonsured monk, buoyed along in a fluffy white cloud in the sky, is strikingly alien. It is this balance between the familiar and the unfamiliar, the universal and the particular, which will exercise me most during my research project.

In my attempt to establish what was *distinctive* about Renaissance piety, I shall be pursuing religion out of the church and into the neighbourhood and the home. It is already clear to me that the Italian household – far from being a site of worldly individualism – was saturated with religious practices and beliefs during this period. New attention to domestic devotions and the rich culture of objects that supported them will challenge our assumptions about the Renaissance mindset. This was a world in which the Virgin and saints were regular visitors, and in which materialism could be good for the soul.

"This was a world in which the Virgin and saints were regular visitors, and in which materialism could be good for the soul."



Dr Mary Laven

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Infrastructure revolution

Technology has advanced to the point where the condition of bridges, tunnels and buildings can be monitored in unprecedented detail. Now a new Centre at Cambridge has been formed to kick-start the smart infrastructure revolution.

London Bridge, so far as we know, is not falling down. Whether we would be able to tell if it was about to, however, is a different question. And, if it was, we would need to calculate how much time it had left, so that we could establish when to deny people and traffic access for their own safety. Such matters have been preoccupying researchers like Professors Robert Mair and Kenichi Soga for most of their careers – and with good reason.

Next to many icons of British infrastructure, London Bridge (39 years old in its present incarnation) is a mere spring chicken. Every day, millions of us use bridges, tunnels and pipelines constructed in the Victorian age. Our cities and towns are densely populated networks of infrastructure, much of it a century old or more. They are shaped by the clash of political and public expectations, but they are also home to some of the most important listed buildings, structures and heritage sites in the world. Given the scale of the job involved in ensuring that Britain's infrastructure remains standing, it seems both astonishing and oddly reassuring that most of it does.

Horror stories about what could happen if it all went wrong sometimes crop up in the news. In 2007, the I-35W Mississippi River Bridge near Minneapolis fell down during the evening rush hour. Thirteen people were killed and more than 100 were injured. This tragedy, it later emerged, was a direct result of the fact that those responsible for maintaining the bridge simply did not know enough about its condition to predict and prevent the collapse.

Yet such ignorance is fast becoming a thing of the past. Thanks to rapid advances in technologies like wireless sensors and fibre optics, it is now possible to keep both old and new infrastructure under constant surveillance, monitoring strain, temperature, displacement, humidity or even a crack in a wall. Researchers believe we are on the verge of developing 'smart infrastructure', which will allow buildings, tunnels, bridges, sea defences, or road and railway cuttings, to be subjected to regular health checks at the touch of a button.

Mair and Soga, both Professors of Civil Engineering at Cambridge, are among a group of academics at the University making that vision a reality. Last year, an Innovation

Knowledge Centre (IKC) for Smart Infrastructure and Construction was set up, based in the Department of Engineering, but involving colleagues from across the University – in the Department of Architecture, the Computer Laboratory and Judge Business School. The IKC works with construction, infrastructure and technology firms. Its aim is ambitious: its founders believe that it could kick-start a new industry dedicated to smart infrastructure and construction in the UK.

“The analogy I use when describing our IKC is that of a car,” Mair said. “A modern car has sensors that can tell you such things as when the brake lights have failed, or the fan belt is broken. Smart monitoring can give us equivalent information about buildings, bridges and tunnels as well.”

In spite of their huge potential, the latest sensor technologies are not routinely used in infrastructure at the moment. The Forth Road Bridge, where corrosion in the main cables has been monitored since 2003, is a rare exception. Mair and Soga believe that we have barely begun to exploit the potential of the latest technologies; little is done to monitor how most bridges are performing and there is virtually no such monitoring of buildings.

Alongside the priority of public safety, there is a strong business case for constantly scrutinising infrastructure. Worldwide, its maintenance costs billions of dollars every year. Even a small percentage improvement in efficiency would engender major savings. “London Underground needs to know if the Northern Line is good for another 20 years, or another 80, or longer,” Mair said. “At the moment, nobody really knows.”

Sensors and optical fibres

One of the aims of the IKC is to develop a new generation of wireless sensors to the point of marketability by 2016. These small devices measure a structure’s physical conditions, such as temperature, vibration and strain. They are ideal for monitoring those parts of infrastructure that cannot be reached with ease, like inside a tunnel or under a suspension bridge.

The Cambridge Engineering Department has already conducted trials with such technology, including one that monitored humidity in the anchorage chambers of the Humber Bridge, where the steel anchor cables have to remain relatively dry to avoid corrosion. Wireless sensors have also been installed to monitor a tunnel on the London Underground, where they measure changes in inclination and cracks.

With wired sensors now a thing of the past, the ‘Holy Grail’, as Mair puts it, is removing the need for batteries. At the moment, the sensors need to have their batteries replaced. One of the IKC’s projects will look instead at using micro-electrical mechanical systems (MEMS), in which miniature devices and circuitry can be etched on to a silicon chip as part of the sensor.

Potentially, a very small turbine could be included to harness the wind power produced by passing trains in the tunnel, making the system entirely self-sufficient. On bridges, similar technology could utilise the vibrations from vehicles.

Optical-fibre monitoring, another key research focus for the IKC, has similarly huge potential. Recently, when a new tunnel was built beneath the century-old Thameslink tunnel in London, Cambridge engineers installed optical fibres around the inside of the old brick tunnel. These produced continuous measurement of the changing strains and temperature at every single point along the fibre. Previously, engineers would have had to use conventional survey techniques to analyse the impact of the new tunnel. Now, optical fibres can be used to measure strain directly and continuously – usually at a cost of just 10 pence a metre.

In 1994, Mair headed the geotechnical group examining the impact of London’s Jubilee Line Extension on the stability of that greatest of British landmarks, Big Ben. Then, huge amounts of meticulous manual measurement went into assessing whether the clock tower was under threat. When boring begins for the huge Crossrail project underneath London this year, he and his team will again be analysing the impact on other buildings, but this time also with fibre optics and sensors. “The technology we have now offers a whole new dimension compared to what was available for the Jubilee Line Extension,” he reflected.

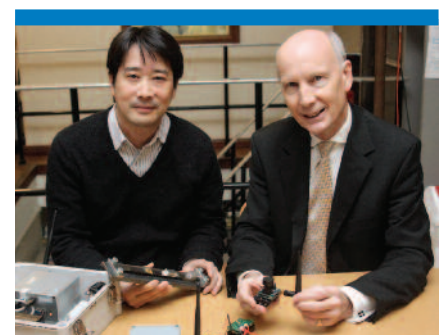
In new structures, incorporating optical fibres during the construction process itself would enable an unprecedented level of ‘cradle to grave’ analysis of how stable our infrastructure is. At the moment, considerable over-estimation goes into the use of many components in buildings and structures to guarantee safety. Better monitoring would allow construction firms to make far more accurate judgements about how much material to use. With technology also enabling the off-site manufacture of building components, it should be easier for these firms to insert sensors and optical fibres into walls, facades and beams, by adding them to components in the factory before they reach the building site – thereby creating the ‘smart’ building.

Smart infrastructure

The IKC has been funded to the tune of £17 million, £10 million from the Engineering and Physical Sciences Research Council and the Technology Strategy Board, and the rest from industry collaborators. By 2016, Mair and Soga hope that the Centre will have advanced both the technology and business cases sufficiently to be able to support its future through industry collaboration alone. If all goes to plan, Britain could by then be well on its way to becoming a centre for smart infrastructure and construction on a global scale. Work is already taking place with partners in the USA, China, Hong Kong and

Japan, parts of the world where monitoring infrastructure is vital given the greater threat of earthquakes and other natural disasters. Mair and Soga have already used optical fibres successfully in a project on the Singapore metro. “The infrastructure of some of these countries is in a state of very fast growth,” Soga added. “Like us, they are starting to realise that smart monitoring could have huge benefits.”

“London Underground needs to know if the Northern Line is good for another 20 years, or another 80, or longer. At the moment, nobody really knows.”



Professor Kenichi Soga (left) and Professor Robert Mair

For more information, please contact Professor Mair (rjm50@cam.ac.uk) and Professor Soga (ks207@cam.ac.uk) at the Department of Engineering (www.eng.cam.ac.uk/).

Flower power: how to get ahead in advertising

Some plants go to extraordinary lengths to attract pollinators. A unique collaboration between plant scientists and physicists is revealing the full extent of botanical advertising.

If you want to stand out from the crowd, you might dress to impress. The world of flowering plants is not so very different. Plants that depend on insect and other animal pollinators to carry their pollen from one plant to another employ sophisticated mechanisms to attract attention, and it's not simply a case of scent, colour and a sugary nectar reward.

The lengths to which flowers go to self-advertise are now being revealed through a collaboration between botanist Dr Beverley Glover and physicist Professor Ulli Steiner. Their research project, funded by the Leverhulme Trust, is characterising how plants signal to pollinators not only through pigments but also through structural mechanisms that modulate light, and their results have important implications for crop productivity.

"Botanists have long known that there are many tricks with which plants attract pollinators but not all are visible to the human eye," explained Dr Glover. "We need to look at flowers like an insect looks at them, using sophisticated optical instruments and measuring ultraviolet (UV) reflection."

Taking a physical optical approach to understanding flowers is a new field, as Professor Steiner explained: "Using modern optical methods such as spectroscopy with high spatial resolution we have been able to study the optical function of surface structures on plant petals and discover something new about how they give rise to structural colour in flowering plants."

Structural colour is the generation of a visible colour independently of chemical pigments by influencing the behaviour of light. A physical structure within the petal reflects a narrow bandwidth of light wavelength, allowing all other wavelengths to pass through to the interior, where they are absorbed. The effect is often a more

intense and pure colour than a pigment creates.

Dr Silvia Vignolini, who works on the project in the Department of Plant Sciences and the Cavendish Laboratory, has been characterising the incidence of structural colour among species of flowering plants. In recently published findings, she showed that the bright and glossy appearance of a buttercup's petals is the result of interplay between two extremely flat surfaces in the epidermal layer of the petal. Reflection of light by the smooth surface of the cells and the air layer below the epidermis effectively doubles the gloss of the petal and reflects a significant amount of UV light.

Many pollinators, including bees, have eyes sensitive in the UV region. "To stand out against the green background, some flowers reflect light at a wavelength best suited to the photoreceptors in a pollinator's eye," explained Vignolini. In the case of some daisies, for example, the researchers have shown that the outer ring of ray florets (petal-like structures) reflects UV, whereas the inner ring does not; this, they speculate, could result in a 'bulls-eye' effect that draws the pollinator towards the centre.

Vignolini's work has demonstrated that some plants produce iridescence through ordered striations in the plant epidermis which, rather like the grooves of a CD, have the effect of creating colour through interference. Remarkably, bumblebees can learn that the shifting colour is a signal of a rewarding flower and can remember that signal even when presented with novel flower colours. The results so far indicate that iridescence has evolved several times in the flowering plant kingdom and is more phylogenetically widespread than previously realised.

The project aims to understand not only the various physical mechanisms by which

plants use structural colours, both at the cellular and genetic level, but also the nuances of how pollinators respond to these signals, as Glover explained: "Knowing how pollinators and plants are linked is important because we don't know to what extent these interactions might become uncoupled as the climate changes. The ranges of plants or animals might move, or their developmental timings might change. The more we understand these interactions, the better placed we are to develop strategies to enhance the signals that make crops attractive to pollinators."

Dr Glover explains the structure of a daisy's head in our newly launched Under the Microscope series: www.cam.ac.uk/research/tag/Under-the-Microscope/



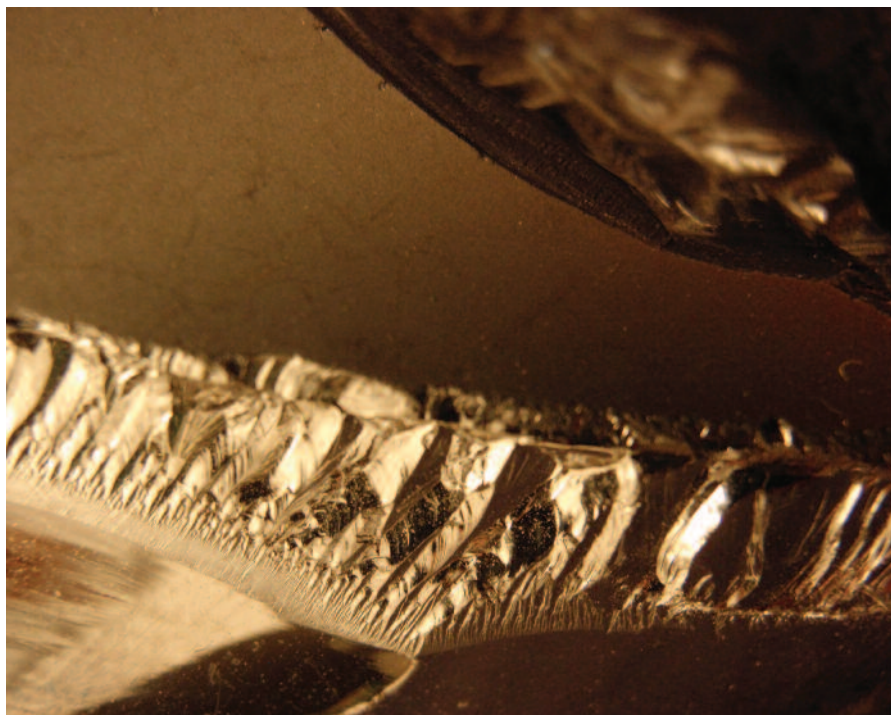
Dr Beverley Glover (left), Dr Silvia Vignolini and Professor Ulli Steiner
For more information, please contact Dr Glover (bjg26@cam.ac.uk) or Professor Steiner (us222@cam.ac.uk) at the Department of Plant Sciences (www.plantsci.cam.ac.uk/) and the Cavendish Laboratory (www.phy.cam.ac.uk/), respectively.



Bees are important pollinators of daisies and many other flowers

Solar-grade silicon at low cost

A new process that has the potential to drive down the cost of manufacturing solar-grade silicon could increase the use of photovoltaic devices for capturing the sun's energy.



Edge of an ingot of silicon, currently the most commonly used photovoltaic material in solar panels

In less than the time it takes to read this paragraph, the sun will have provided as much energy to Earth as used by all of human civilisation in one day. No wonder that, as electricity prices increase, more homeowners and businesses are opting to harness this energy by installing solar panels. Yet, despite the huge opportunities solar power affords as a renewable source of energy, it still represents a small fraction of our current capacity to generate power.

One factor holding back the growth of the photovoltaic (PV) industry, which provides the modules that make up a solar panel, is the high cost of the solar-grade silicon on which it currently depends. Moreover, the manufacturing methods commonly used to make crude silicon produce some 10 tons of CO₂ for every ton of silicon produced, and the refinement stage (the Siemens process) produces a further 45 tons of CO₂ as well as toxic gases.

"It's somewhat ironic that such an environmentally destructive process supplies 95% of the silicon required by the PV industry to harness a clean and sustainable energy source," said materials scientist Dr Antony Cox. "In fact, a solar cell fabricated with the Siemens process would need to be operating for up to six years to match the same energy required to make it."

Cox has been developing and up-scaling a new process to make solar-grade silicon that he estimates will cut energy consumption and costs by 80% and CO₂ emissions by 90%. Based on a procedure known as the FFC Cambridge process developed by Professor Derek Fray and colleagues in the Department of Materials Science and Metallurgy, the new modification has extended FFC to silicon for

the first time and is now in its final research and development stages.

For PV cells to work, there must be no impurities in the silicon that could sabotage the movement of electron charge carriers within the material. When photons of sunlight strike the PV cell, their energy is absorbed by the semiconducting silicon, exciting electrons into a higher energy state and creating an electric current.

Although various new materials are under development, silicon is the most commonly used material in PV cells today. Numerous attempts have tried to find a new process for producing solar-grade silicon but, as Cox explained: "All are energy intensive, with a myriad of complex stages, and none has become a commercial process that can compete with the production scale and product quality of the Siemens process."

The two-stage process he has been developing uses white sand and calcium chloride (a product used commonly in the food industry) as raw materials. First, tablets of compressed sand are immersed into the calcium chloride electrolyte and heated to 900°C. The silicon in sand is present as an oxide and, during the FFC process, the oxygen atoms are ionised, migrate to the anode and are discharged as oxygen, which is the only by-product of the reaction. Sand is not easy to reduce to silicon and Cox has spent the past four years solving this fundamental challenge and up-scaling the first stage of the process.

In the second stage, an electrorefining process within the same cell takes silicon from 99.99% purity to the Holy Grail of 99.9999% purity. "Preliminary investigations were very encouraging and we are now developing the second stage," said Cox,

whose research was funded by the Engineering and Physical Sciences Research Council.

"Crucially, this process requires minimal energy consumption, generates O₂ rather than CO₂ as a by-product, and is easily up-scalable because it involves fewer production stages," he added. "Many attempted scale-ups for other processes have been thwarted due to the sheer difference in scale between a pilot plant and a commercial plant." Based on the results of an independent economic survey, he believes that the process will drive down the cost of manufacturing solar-grade silicon from around the current \$40–200/kg to a maximum of \$8/kg, making solar power a more affordable option to generate power.



Professor Derek Fray (left) and Dr Antony Cox

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It's *not* history

Cambridge linguists have pieced together the curious evolving history of the word *not* across the languages of Europe. In doing so, they suggest that overuse of words such as *literally* may be a natural linguistic development.

What would we do without the word *not*? Language depends on negation: 'the defendant is *not* guilty', 'it's *not* fair', 'it's *not* you, it's me'. *Not* can impart a subtlety of meaning to speech, as in the chastising 'are you *not* home yet?' compared with the query 'are you home yet?' But little do many of us realise that the word has a fascinating linguistic history, involving a pattern of change that has been echoed again and again in languages across the globe.

Now, research at the University of Cambridge has traced how and why the words used to express negation have changed in the languages of Europe and the Mediterranean over the past millennium. Led by Dr David Willis at the Department of Theoretical and Applied Linguistics, the study is the first comprehensive attempt to look for patterns across such a breadth of languages and over such a timescale. It has also involved the first systematic analysis of the history of negation in languages such as Arabic, Berber, Breton and Welsh.

Not only does the new research on the history of *not* provide a better insight into how languages evolve, and indeed provides a marker of the stage at which a language has reached in the evolution of negation, but it also sheds light on how emphatic words such as *literally* creep into common parlance.

Jespersen's cycle

It was at the turn of the 20th century that a linguist named Otto Jespersen discovered a cyclical pattern in how languages express negation. Put simply, the cycle moves from a single word meaning *not*, placed before the verb (stage I), through a stage in which two words are used either side of the verb (stage II) and then back to a single word after the verb (stage III).

Jespersen's idea was that at some stage the original negative word is found to be insufficient to express negation and becomes strengthened by a second, emphatic word. In due course, the emphatic word is used so frequently that it becomes the only word needed to express the negative view and the first word drops away.

Many different languages have independently gone through this cyclical

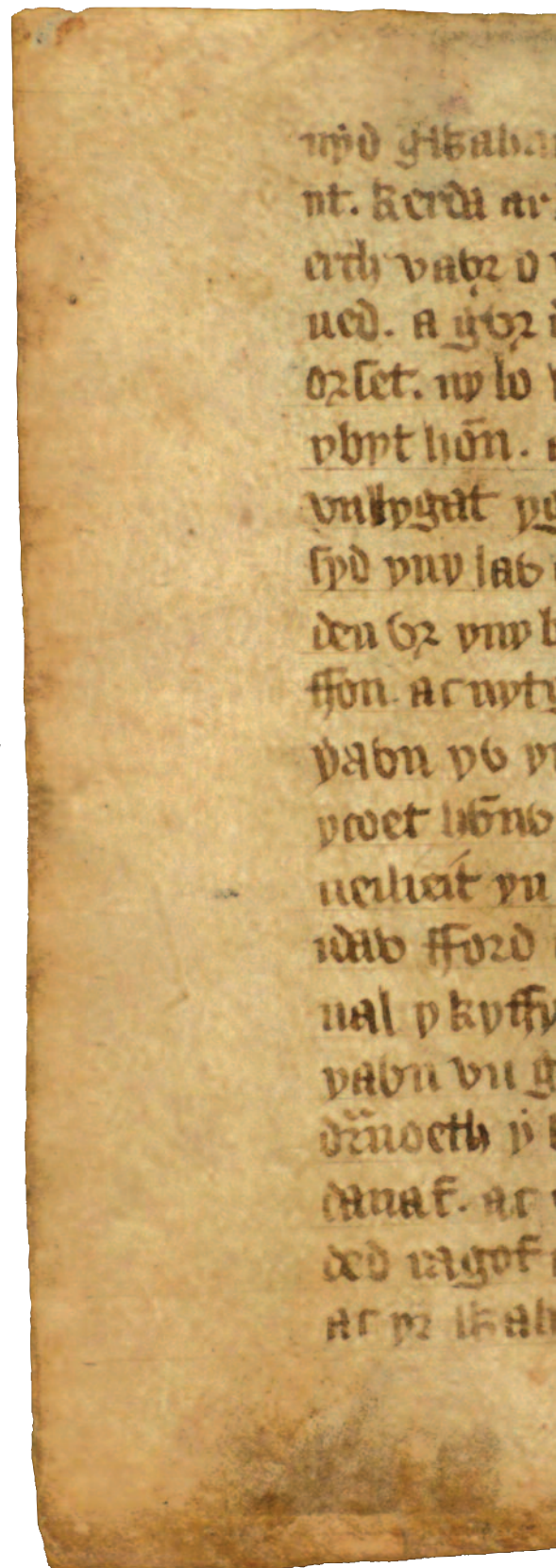
evolution, and have done so at vastly different times in history. Take French, for example. To say *I don't know* in Old French, *ne* was used before the verb (as in *Je ne sais*) until about 800 years ago, when it became strengthened to the *ne...pas* version (*Je ne sais pas*) that we recognise today. And this is largely how it has remained: "Standard French is effectively at stage II of the cycle," explained Willis. "In everyday spoken French, people are losing the *ne*, but children are taught to use the full two-word form of the negator. With this conservative influence, it will be interesting to see whether the language will complete the cycle or stay indefinitely at stage II."

English, on the other hand, had finished its cycle by the mid-14th century, moving from the Old English *ne* before the verb, to the strengthened *ne...nawit* (nothing) in Middle English, to the simplified, post-verbal *not* of Early Modern English. And some languages completed the cycle even earlier, such as Scandinavian, which had completed the cycle before written records began, as shown through the reconstructed history of the language. Other languages such as Spanish or Russian have yet to begin the cycle.

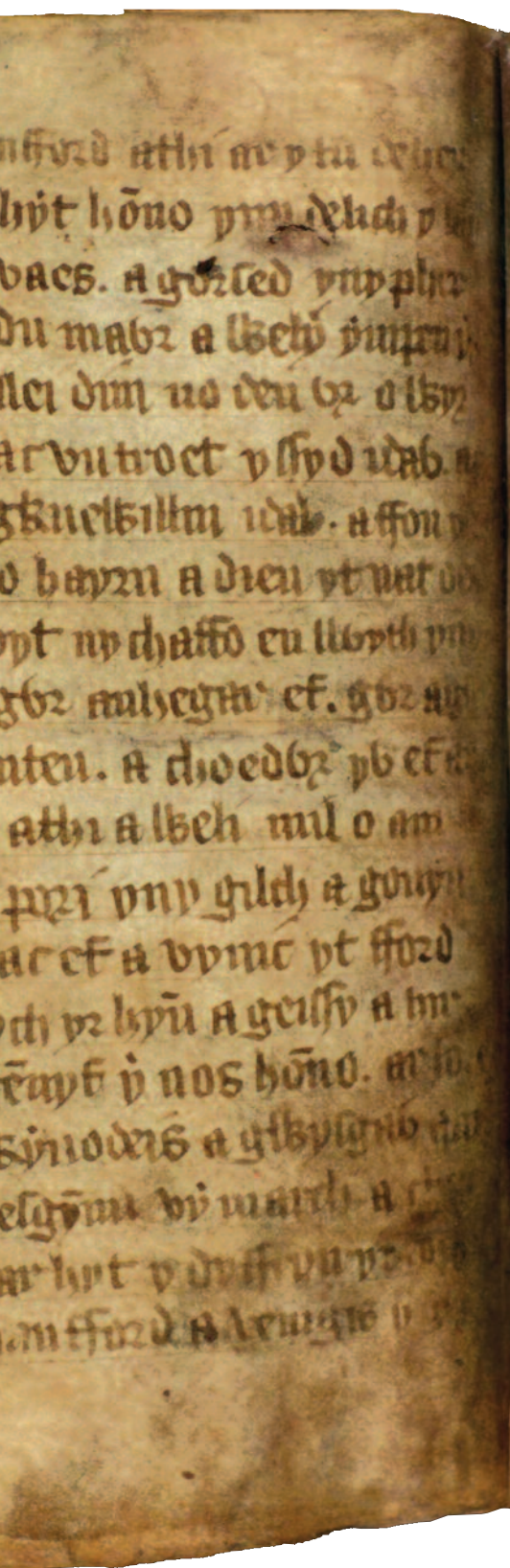
"Cycles of usage such as that seen in negation appear to be a normal part of language development," continued Willis who carried out the research with Dr Anne Breitbarth and Dr Chris Lucas. "We are interested in what these cyclical developments are and what they tell us about why languages change. The results have helped us draw out a new understanding of how language contact, language acquisition, and psychological and social factors might influence the evolution of language in the past and in the future."

Patterns and pathways

To complete the study, which was funded by the Arts and Humanities Research Council and is resulting in a series of publications including a two-volume book in 2012, vast amounts of written texts were analysed for examples of stage I, II or III expressions. Up to a thousand years of linguistic history were interrogated to observe Jespersen cycles in



One of the earliest instances of written use of the new *not* in Welsh, found by Dr Willis in one of the *Mabinogion* romances contained in a late 14th-century Welsh manuscript (Jesus 20) at lines 4–6, which reads 'and a big dark man you will see at the end of the mound who is not at all (*dim*) smaller than two men of the men of this world'



THE PRINCIPAL AND FELLOWS OF JESUS COLLEGE, OXFORD

some languages. Fieldwork interviews were used to resolve how negation is used in spoken Arabic, where the written form is distinct and conservative.

"One of our greatest difficulties was working out when a change in the expression of negation was meant emphatically or not," said Willis. "This can tell us at what stage the language is at. At the transition between stage I and II, a second word starts being used as a means to emphasise the negative. When it is used more frequently, the language progresses to a stage when the first word is dropped, and stage III is complete."

For Welsh, the researchers identified the emphatic use of the negative by comparing Welsh and English versions of the Bible. "In Welsh, *ni* was the first negator, with *dim* or *ddim* coming into use sporadically for emphasis from the end of the 13th century. In the 16th and 17th centuries, usage went up enormously. Welsh then remained in stage II for about 200 years and then moved into stage III, dropping the use of *ni* around 1820."

The team's discovery that Welsh only began Jespersen's cycle at the time that English had completed it helps to answer why different languages show different cycle lengths. In some cases, the researchers can point towards one language influencing the development of a nearby language. For example, the initiation of Jespersen's cycle in North African Arabic dialects was triggered by contact with Coptic in Egypt at the end of the first millennium. But just as often, as in the case of Welsh and English, contact seems to have no effect and Jespersen's cycle progresses independently. "We believe that stage II is generally unstable and that prescriptive pressure, as seen in French, can sometimes retard progression from stage II to stage III," said Willis.

The influence of emphasis

One question the study has considered is how a word that is used emphatically to strengthen certain phrases becomes mainstream. The researchers believe that language acquisition by children has a role to play in this type of language change, as Willis explained: "We suggest that adults initiated using the second negator emphatically for

certain verbs, usually as part of a measure phrase, as in *It didn't help a bit*, but that children misinterpreted this, and extended use of the emphatic negator to all phrases." The effect is called bleaching: essentially where the meaning of a word is reduced or broadened.

An example of bleaching that many will be aware of today is the linguistic misuse of the word *literally* (as in *I literally ran all the way*). "Although it strictly means the literal use of a word, for some it now means that they have a strong emotional commitment to what they are saying," explained Willis. "The word has caught the eye of prescriptivists, who dispute its overuse as an emphatic, and it has also become quite generally overtly stigmatised. This may well impede a natural linguistic development of just the same kind that we have seen time and time again for the development of negation in different languages across the whole of the last millennium."

"Cycles of usage such as that seen in negation appear to be a normal part of language development."



HOWARD BEAUMONT

Dr David Willis

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Extreme Sleepover: breathless at Everest Base Camp



Dr Andrew Murray (right) with his colleagues Dr Nick Knight and Dr Cameron Holloway on the approach to Everest Base Camp

Physiologist Dr Andrew Murray studies his own and others' responses to extreme altitude as part of a programme that will improve hospital treatments for critically ill people. Here, he describes what it's like to be breathless at Everest Base Camp.

I won't sleep well tonight, not with the nightmarish sounds coming from the sleeping bag next to me. Nick, my PhD student (and currently tentmate), has been struggling to control his breathing for the past hour, and as each breath becomes lighter than the last, I recognise the classic signs of what physiology textbooks call Cheyne–Stokes respiration. Momentarily, I wish that my undergraduates were here to witness this, but suddenly, with a bone-rattling gasp, Nick sits bolt upright, flinging open his sleeping bag and drawing in breath after desperate breath. As he settles down, drifting back to sleep, the cycle begins again, and I am left wondering whether to be more perturbed by this human terror or the external soundtrack to our evening – the distant rumble of an avalanche on the South Col and the shotgun-like cracks in the ice of the Khumbu Glacier on which our tent is pitched.

However, my most pressing concern is closer to home. My kidneys have been working overtime to fine-tune my blood pH, helping me to acclimatise. It's sparing me from the periodic breathing that is troubling Nick, but it's not easy to get comfortable on a

camping mat, and right now my bladder is fit to burst. I'd make the short trek to the toilet tent, but it's -20°C outside and a toasty -7°C in the tent, so I'm not heading anywhere until morning. No, I won't sleep at all well tonight, but then again, I never do on my first night at altitude.

In the morning, the world feels very different. I'm breathless from simply pulling on my boots, but as I step blinking into daylight, I gaze around me at the mountain giants that have been keeping watch over our restless night: Pumori, Lhotse, Nupste, and the mother goddess of the world herself, Sagarmatha – Mount Everest. Strange pillars of ice rise around us in stark, desolate contrast to the glistening waterfalls and lush rhododendron forests we trekked past on our way here. No rock flowers here and no birds; just a few dozen yaks and 5,000 tents to remind us that this is not some lifeless alien planet, but an extraordinary environment on the roof of our own Planet Earth.

Everest Base Camp, deserted three weeks ago, has been transformed into a hustling, bustling, cosmopolitan canvas city constructed upon rock and ice – a living,

breathing epicentre of the world's mountaineering ambition. Next to our camp, a Malaysian expedition, the first from that country, is raising their national flag, and on a hillock nearer the icefall, the Scouts have set up their camp for the season. Their base camp manager scuttles between tents, wielding a satellite phone and messages from home, while an expedition Sirdar nonchalantly fries eggs for the lads' breakfast, using only the magnified light of the brilliant morning sun as fuel. As brightly coloured prayer flags flap and fall in the breeze, sounds of a puja ceremony greet us from across this makeshift metropolis. Reverent chanting gives way to the celebratory clanging and banging of pots and pans. The climb has been blessed, and a team are readying themselves for departure. The wise and wizened climbing Sherpa checks his trusted ropes, while the Everest first-timer fiddles nervously with the buckles on her pack, gazing upwards towards her magnificent, deadly destination.

The views take away whatever breath we have left, but there's little time this morning for idle wonder. We're here as members of Caudwell Xtreme Everest, a large-scale medical research expedition, attempting to understand how our bodies respond to low oxygen at extreme altitude in order to help critically ill patients at home, for whom low oxygen can be life-threatening.

Before breakfast, we complete our diaries – some are simple measures of mood, appetite and headache, but there's also a step test, throughout which we monitor heart rate, blood pressure, haemoglobin saturations and breathing rate. The test that was light exercise back in London and Kathmandu feels Herculean up here where there is half the oxygen to which our lowlander bodies are accustomed. I pity our teammates struggling with the same test 1,000 metres above us in the Western Cwm. The tests get tougher, though I'd far rather pedal to exhaustion on an exercise bike than give another blood sample; I never did get along with needles. Most embarrassing though for an academic are the cognition tests. What was a doddle at sea level becomes mind-bendingly impossible at this altitude. I struggle to recall a list of 15 memorable words or join together some numbered dots.

As the light fades and temperatures plummet, we make our way to the mess tent. Exchanging stories of red blood cell counts and resting heart rates, we while away the evening until it's time for bed once more. Stepping outside, I notice a clear night sky awash with constellations and spend a moment counting satellites and shooting stars. Another light blinks at me from high on the ridge above the icefall. A head-torch: perhaps one of our own team preparing for the next stage of their summit attempt. I'll sleep really well tonight, I always do on my second night at altitude.



ANDREW MURRAY

Sherpas set up camp in the rock, ice and rarified air of Everest Base Camp, while a yak looks on

Extreme Sleepover: the series

If you missed the recent series of reports from Cambridge researchers describing their extreme sleepovers, you can read all 12 at www.cam.ac.uk/research/tag/Extreme-Sleepover/

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"I'm breathless from simply pulling on my boots, but as I step blinking into daylight, I gaze around me at the mountain giants that have been keeping watch over our restless night."



Dr Andrew Murray

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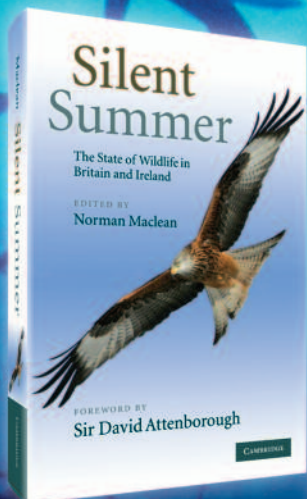
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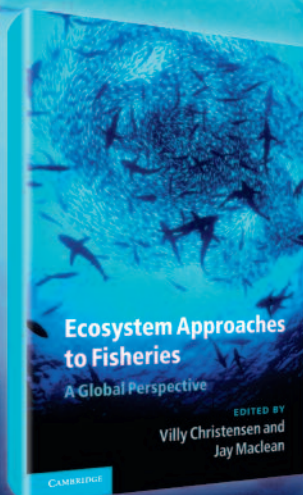
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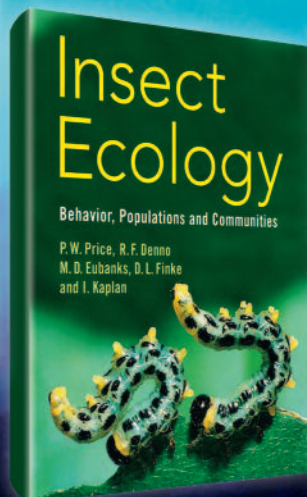
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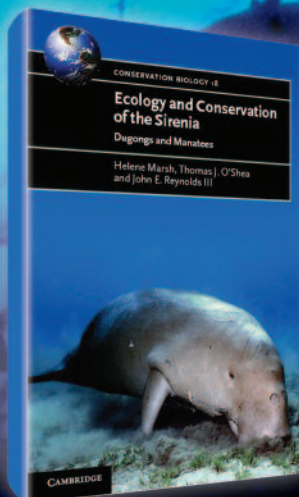
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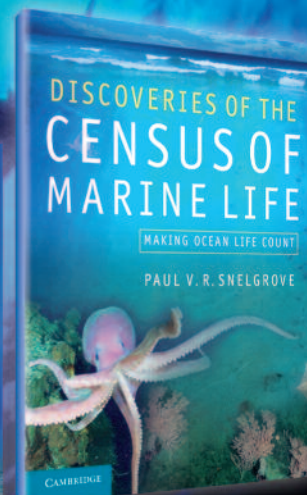
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