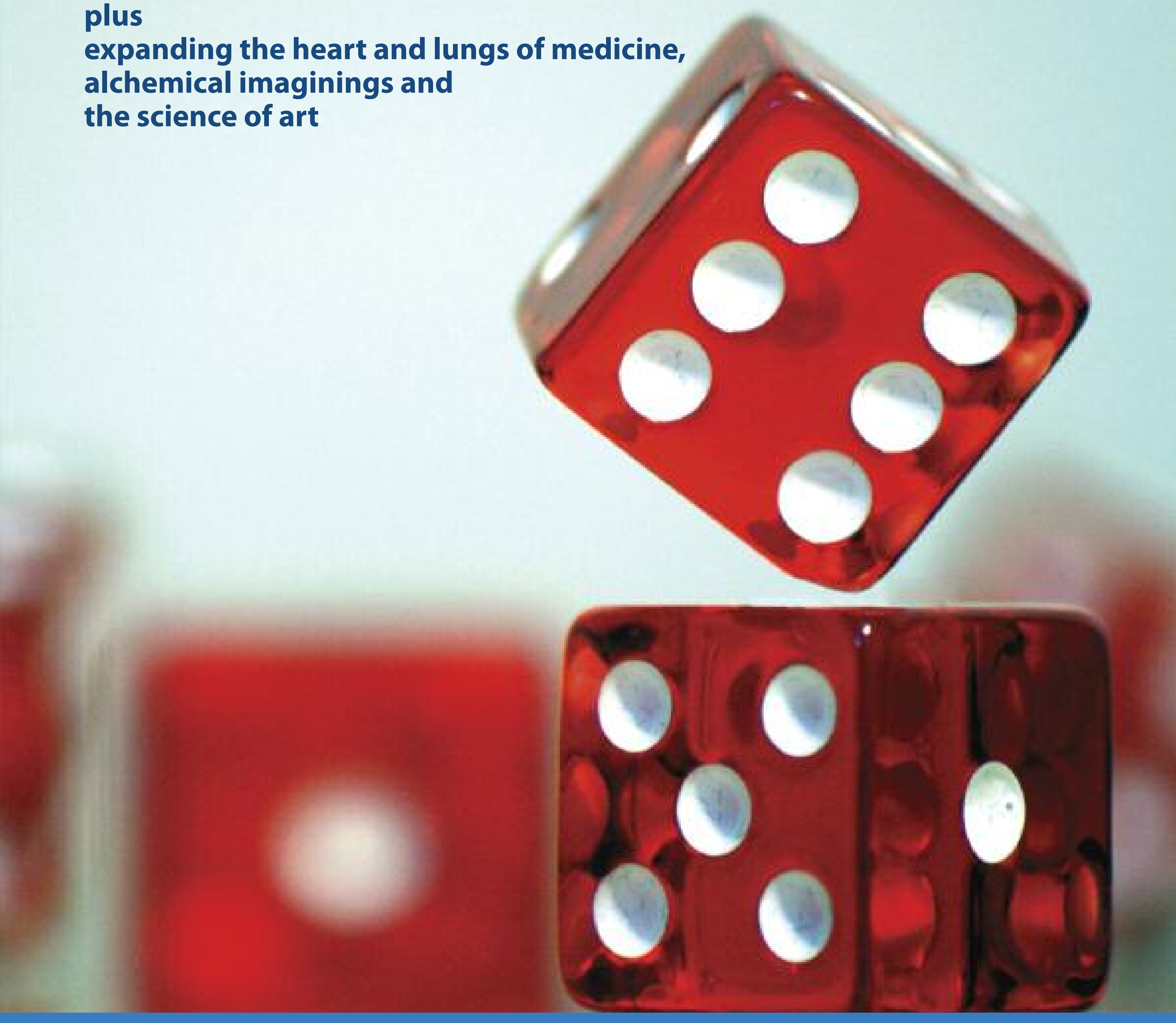
RESEARCH HORIZONS

In this issue

RISK AND UNCERTAINTY

plus
expanding the heart and lungs of medicine,
alchemical imaginings and
the science of art



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Risk and uncertainty

MARK MINISZKO

None of us know what is going to happen in the future, either to ourselves or to society. Yet we still have to make decisions, whether it's a personal dilemma (should I cut down my drinking?) or a political choice (should there be a minimum alcohol price?). Making important decisions in the face of uncertainty is unsettling and difficult, and so is a vital area of academic research.

The articles in this issue represent just a fraction of the relevant activity going on in Cambridge, and an appropriately wide range of disciplines and approaches. From cybercrime to earthquakes, influenza to air travel, the topics reflect issues that are of crucial importance. It is an extraordinarily diverse area, although many informal interactions are increasingly focused on the Centre for Risk Studies, in the Cambridge Judge Business School, and the Centre for Risk in the Built Environment, in the Department of Architecture. The inclusion in this issue of discussion of the National Risk Register by John Tesh, the Cabinet Office official responsible for the Register and Policy Fellow at the Cambridge Centre for Science and Policy (CSaP), also reflects the growing role of CSaP in promoting engagement between policy professionals, business leaders and experts in the sciences and engineering.

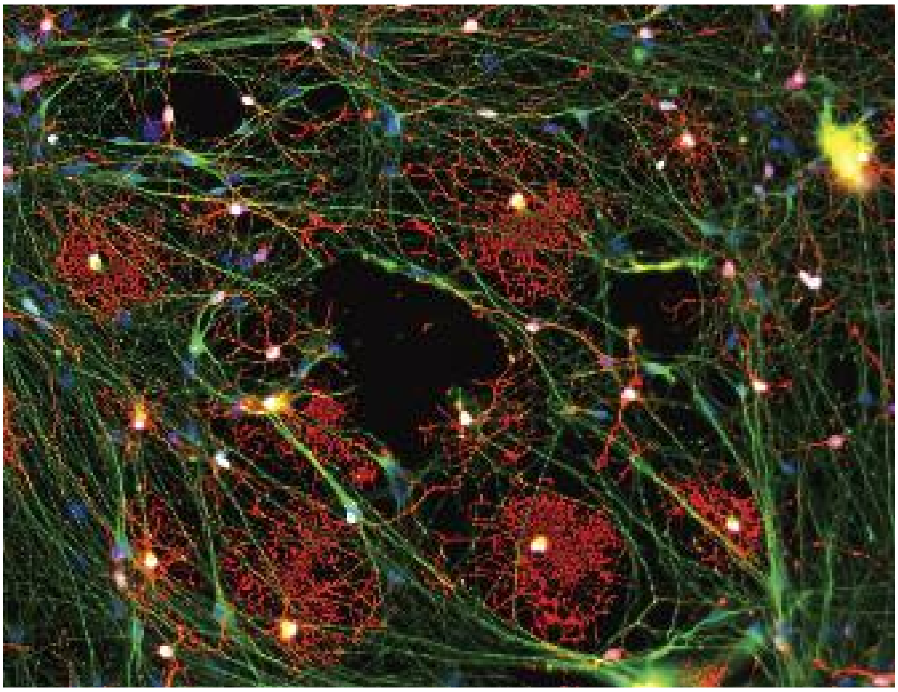
But what do we mean by risk and uncertainty? A common distinction is as follows. If we feel we understand what is going on, and have some confidence in our assessment of the chances of different futures, then we can say we are dealing with *risks*, and can hope to produce a numerically balanced judgement. When we have the humility to acknowledge that we cannot put numbers on everything, then we are dealing with deeper *uncertainty,* and may instead aim for resilience to surprises. Much of the research described here is attempting to extend the domain that can be adequately quantified.

Finally, there has been a traditional division between risk assessment (what are the risks?) and risk management (what should we do about them?). This issue of *Research Horizons*, however, shows that this is not so straightforward – how we analyse threats is closely connected to what we might be able to do about them. Academics need to be grounded in the real world in order to know both what is important and what is feasible, and the following examples display just such engaged research.

Professor David Spiegelhalter
Winton Professor for the Public Understanding of Risk
understandinguncertainty.org

Wellcome Trust and Medical Research Council invest in world-class Stem Cell Institute

Two of the UK's largest funders of medical research are to invest £8 million in a new world-leading centre for stem cell biology and medicine.



SYBIL STACPOOLE, CAMBRIDGE CENTRE FOR MYELIN REPAIR

Oligodendrocytes (red) derived from human embryonic stem cells

The Wellcome Trust/Medical Research Council (MRC) Cambridge Stem Cell Institute will advance our understanding of stem cells and their potential to treat a range of life-threatening conditions that currently have no effective cures.

Building on existing investment by the MRC and the Wellcome Trust, the Institute will unite 30 leading research teams with expertise across the three main types of stem cells: embryonic, adult and induced pluripotent cells (body cells that have been treated to behave like embryonic stem cells).

Research scientists will work alongside technology specialists and doctors to develop new therapeutic approaches underpinned by a strong base of fundamental stem cell biology. Located in Cambridge, the Institute is near the largest cluster of biotechnology companies in Europe, allowing unrivalled opportunities for industry collaboration.

Stem cells can renew themselves almost indefinitely and can develop into any of the cell types in the body. They are an invaluable tool for scientists studying the mechanisms of human disease and could be used as an alternative to animal models by pharmaceutical companies developing new drugs. They also show great promise as potential treatments for devastating conditions such as liver disease, diabetes, blindness, spinal cord injury and neurodegenerative disorders like Parkinson's disease.

"The Wellcome Trust/MRC Cambridge Stem Cell Institute will be an invigorating environment for cross-fertilisation between fundamental and translational researchers," explained Professor Austin Smith, Director of the new Institute. "Our aim is to close the knowledge gap and drive stem cell research forward towards clinical applications. The world-class facilities will attract the best international talent from the fields of stem cell biology and regenerative medicine to pursue this goal."

"This joint funding initiative from the Wellcome Trust and MRC gives us the opportunity to link Cambridge's great strengths in stem cell biology with our strengths in translational clinical research, and thus to give new insights into disease mechanisms – and ultimately to develop new therapies," added Professor Sir Patrick Sissons, Regius Professor of Physic. "In association with the initiative, we all look forward to the future co-location of stem cell biology and medicine in the new building planned for the Cambridge Biomedical Campus."

It is intended that the Institute will eventually be housed in a purpose-built 8,000 m^2 facility to be constructed on the Cambridge Biomedical Research Campus.

For more information, please visit www.stemcells.cam.ac.uk

University Library project helps preserve digital legacies

New resources have been launched to help academics successfully manage and preserve their digital material for the future.

Increasing amounts of research material are now being produced, collected and stored in digital form, and scholars across all disciplines have become not only the creators but also the consumers, curators and archivists of their own digital assets. For the past nine months, PrePARe, a project managed by the University Library's digital repository team and funded by JISC, has been exploring how research staff and students at the University of Cambridge are dealing with these changing roles.

Having interviewed researchers across the University to identify their attitudes, experiences and needs relating to digital management and preservation issues, the team found that although scholars wanted to protect their digital legacy, a lack of either guidance or time often meant that digital preservation was treated as a low priority.

Now, aiming to advise on good practice and to raise awareness of digital preservation generally, the team has responded by delivering simple guidance centred around four key signposts: 'Store it safely', 'Explain it', 'Share it' and 'Start early'. New online resources have been created, training modules are being integrated into the University's graduate training provision, and a cross-disciplinary seminar series has been organised.

"Managing data well ensures research integrity and replication, provides opportunities for researchers to discover and share information, and increases the longevity of research," said Grant Young, the Library's Digital Preservation Manager. "The PrePARe project aims to provide researchers with the guidance they need to ensure that their digital research material can have a lasting impact."

For more information, please contact Barbara Bültmann, PrePARe Project Manager (bb342@cam.ac.uk) or visit www.lib.cam.ac.uk/dataman

Care in the community

A new study will investigate the emotional and economic consequences of what care in the community meant to 18th-century families.

'Madness', James McArdell, after Robert Edge Pine 1760

When institutionalised care for the mentally disabled was phased out under Margaret Thatcher in 1983, and the responsibility for care shifted principally to family members, the policy was considered to be one of the biggest political changes in the history of mental healthcare. But the approach to care was really coming full circle.

Mental illness and disability were family problems for English people living between 1660 and 1800. While mental illness was a subject of morbid fascination to the English public, and queues formed to see incarcerated women, the reality was more mundane. Most women and men who were afflicted by mental illness were not institutionalised in asylums and instead were cared for by other family members.

Now a new study by Cambridge historian Dr Elizabeth Foyster will reveal the impact on families of caring for mentally ill and disabled relatives.

Much has been written about the insane themselves but few studies have considered mental illness from the perspective of the carers. The lifetime burden of caring for those individuals whose mental development did not progress beyond childhood has been little explored. Foyster's research, which has been funded by the Leverhulme Trust, will unpick the emotional and economic consequences for families at a time when the Poor Law bound them to look after their mentally ill and disabled family members.

By asking key questions about the impact of 'care in the community' in the 18th century, Foyster hopes that her research will bridge social and medical history. Specifically, she aims to provide an historical perspective to contemporary debates such as how resources can be stretched to provide for children with learning difficulties and an ageing population.

"The stresses and strains of family life were exacerbated by high infant mortality and low life expectancy, and many individuals were pushed towards mental breakdown," she explained. "Moreover, inherited conditions, senility and what today would be described as 'special needs' could put great emotional demands on family members who had primary responsibility for their sick or disabled relatives."

"The family must have seemed an inescapable feature of daily life between 1660 and 1800. Although there were those who were abandoned and rejected, for the majority, insanity and mental disability was accommodated within the family unit. I aim to get to the heart of what this really meant for people's lives."

For more information, please contact Dr Elizabeth Foyster (eaf21@cam.ac.uk).

Risk test for breast cancer

A test based on research conducted in Cambridge effectively measures a woman's risk for developing certain forms of breast cancer.

Breast cancer affects one in nine women in the UK, and one in eight in the United States. It's by far the most common cancer diagnosed in women, with approximately one million new diagnoses made each year.

A woman's risk of developing breast cancer is determined by both her genes and her lifestyle. Mutations in some genes, such as BRCA1 and BRCA2, greatly increase a woman's risk of developing breast cancer; however, women with mutations in either or both of these two genes represent fewer than 10% of breast cancer cases. Most women who develop breast cancer have little or no family history of the disease.

BREVAGen is a simple two-part test that can help determine a woman's five-year and lifetime risk of developing non-familial breast cancer, and was developed based on research carried out by the University of Cambridge, Cancer Research UK and collaborators worldwide.

In the largest study of breast cancer genetics ever conducted, researchers collected and analysed the DNA of more than 50,000 women in order to complete the first full-genome scan of the disease in 2007. The study, led by Professor Sir Bruce Ponder and Professor Doug Easton, identified breast cancer susceptibility markers that are present in approximately 20% of cases in the UK.

Cambridge Enterprise and Cancer Research Technology licensed the markers in 2009 with the aim of using them to develop and commercialise a diagnostic test, and the BREVAGen test was launched by the Australian company Genetic Technologies Limited in 2011.

The BREVAGen test helps to identify women at increased risk so that their health can be more positively managed (such as through increased surveillance, risk reduction or chemoprevention). Approximately 30% of women are reclassified into a different risk group after BREVAGen testing.

The BREVAGen test is commercially available in regions throughout the United States and Australasia, and plans are in place to launch it in Europe in the near future.

Meanwhile, further research mainly led by Cambridge has identified more than 25 susceptibility markers for breast cancer. Use of these markers, together with other risk factors, should improve predictive tests even further.

For more information, please contact Dr Iain Thomas (iain.thomas@enterprise.cam.ac.uk) at Cambridge Enterprise.

Mastering public policy

A new Master's Programme in Public Policy will equip policy makers with the tools to make effective and informed decisions.

Whether it's setting the agenda on renewable energy, cutting cybercrime or determining alcohol pricing policy, governments face challenges that require measured approaches based on rigorous analysis of the evidence. Now, a new Master's in Public Policy (MPP) being launched by Cambridge's Department of Politics and International Studies aims to encourage long-term thinking and better strategic planning among policy professionals.

The course, which will take its first students in October 2013, draws on teaching from across the University, as well as from professionals in the policy world, to provide a thorough grounding in practical and theoretical aspects of policy making.

Director of the MPP, David Howarth, a Reader in the Department of Land Economy and a former Member of Parliament, explained how the course aims to help policy making: "It's important to make sure that enough people in the political system respect evidence and rational argument. Policy makers can't be experts in all areas but we aim to equip them with the broad range of skills needed to understand the types of evidence there is and the questions to ask."

During the one year course, students learn about the nature of evidence through a series of substantive case studies. They will also participate in simulations and experience first hand how complex messages are negotiated and communicated under intense pressure. Such skills are essential to equip policy makers with the tools to promote urgently needed new thinking on national, European and global challenges.

A further aspect of the course, explained Howarth, is to encourage policy-related research across the University: "The Master's is the first major output of the Cambridge Public Policy (CPP) initiative, which has been set up to promote and support public policy research and teaching at the University. The course provides a focus to build capacity at the University to respond to opportunities in policy research and analysis."

The CPP initiative and development of the Master's were made possible by generous support from The Constitution Society. Sponsorship opportunities are available to support dedicated scholarships, as Dr Miranda Gomperts, one of the key organisers of the Programme, explained: "We hope to attract students from a broad range of areas and it's essential that we can attract the very best irrespective of their financial circumstances."

For more information, please visit www.cpp.csap.cam.ac.uk/mpp

Share and share alike

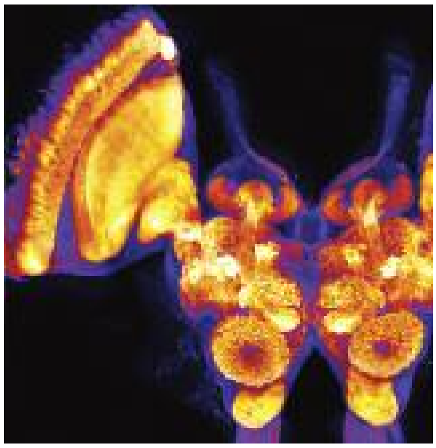
A recently launched database will help researchers seek out and access high-value equipment across five universities.

In today's climate of cutbacks and austerity measures, opportunities to increase efficiency and reduce costs are sought after. With this in mind, a new resource launched by the University of Cambridge aims to improve research management by making greater use of existing equipment and facilities, and by sharing these between universities wherever possible.

The online Research Facilities and Equipment Database will help academics access information about facilities, equipment and research services across the University. As the database expands, researchers will be able to look for, and use, equipment across five partner universities in the project – Cambridge, Imperial College, University College London, and the Universities of Oxford and Southampton.

The initiative is part of a drive by the Research Councils UK to increase the effectiveness of equipment use. Universities are now required to check with other peer institutions to see if there is an opportunity to share equipment before submitting grant applications. The database will facilitate this process and help researchers make a stronger case for new research facilities and equipment in grant applications.

Led by Cambridge's Research Office and funded by the Engineering and Physical Sciences Research Council, the project has already amassed information on over 300 high-value research facilities. Importantly, the database neither monitors nor controls access to these facilities and equipment, as access remains at the equipment owner's discretion, but it does provide an indication of their current usage levels, ranging from 'very low' to 'fully utilised'.



SWIDBERT OTT

Confocal laser scanning microscopy of a locust brain

Professor Lynn Gladden, the Pro-Vice-Chancellor for Research said: 'The Equipment Project has been an excellent example of research-intensive southern universities working together to pool resources at a time of significant funding constraints. Sharing research equipment is not a simple matter, nor is it always feasible and it certainly requires trust between the different researchers involved. Yet, allowing others access to equipment has, in the past, helped to strengthen burgeoning research collaborations and, occasionally, even led to serendipitous collaborative research findings. With budgetary constraints likely to continue, tools such as these are invaluable if we are to support our world-class researchers and help them to accomplish their intellectual endeavours with the best resources available."

For more information, please visit www.equipment.admin.cam.ac.uk

How risky is your breakfast?

Understanding how the numbers add up in relation to risk can help us deal with our own uncertainty, as David Spiegelhalter, Winton Professor for the Public Understanding of Risk, explains.

Like it or not, risks get communicated to us every day. Whether it's the climate, the euro crisis or the booze, someone is warning us to change our ways or we may be in trouble. We may get irritated by all this finger-wagging, but there is a serious science that can be applied to all these messages.

Let's assume we want to communicate some risk. Are we trying to inform people or persuade them to do something? The traditional view is that these were much the same thing: the public are 'irrational' because they are ill-informed, and so if we just educate people then they will not hold misguided beliefs and do silly things.

Fortunately this 'deficit model' has been superseded by a slightly more sophisticated view, which recognises that people vary considerably, and that their reactions and behaviour are not going to be primarily influenced by the information they receive. Their 'affect' – that is the overall positive or negative feeling of individuals towards a potential hazard – is vital, and this is influenced by context, culture and habit. These feelings can be tricky to change, and the simple provision of information can have minimal influence. In contrast, the advice of a trusted source can be crucial.

This may appear rather discouraging, but we have an ethical duty to provide transparent information so that people can, if they wish, weigh up the pros and cons, set their own risk threshold and decide what to do. This is the mind-set underlying the Winton Programme for the Public Understanding of Risk; our team tries to explain risk and debunk myths by engaging the public through stories, creating attractive graphics and entertaining animations, and explaining the ideas behind the numbers.

So what are ethical and transparent representations? First, we need to recognise that there will always be an emotional aspect to the communication, whether it's the images used or even the colours. Advertisers exploit this all the time. Second, more philosophically, I would argue that there is no 'true risk' in the sense that these chances and values actually exist as part of the outside world – they are constructed on the basis of our judgement and knowledge. This means we have to use metaphor and narrative to communicate.

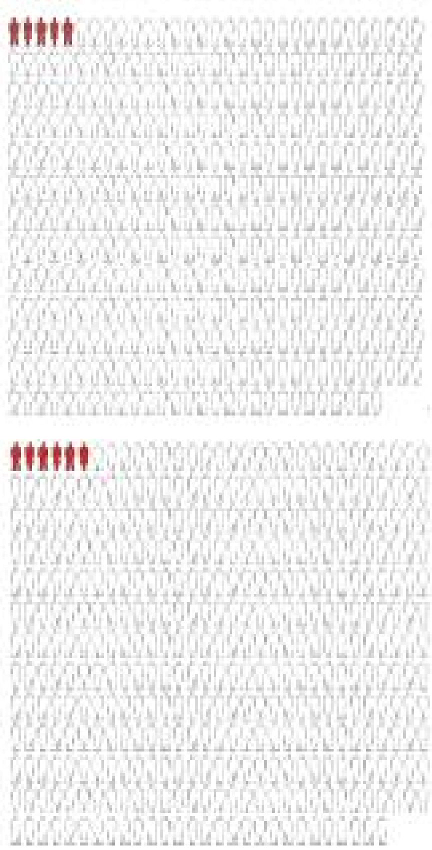
Let's assume that we are willing to put numbers on the chances. For example, a recent newspaper story reported a 20% increased risk of developing pancreatic cancer per 50 g of processed meat eaten per day. Such *relative* risk formats have been shown in controlled trials to exaggerate the magnitude of effects, and so instead it is recommended (and even mandated by the Association of the British Pharmaceutical Industry) that *absolute* risks are used. The lifetime risk of developing pancreatic cancer is 1 in 80; however, if we look at this risk in terms of how many people out of 400 might be expected to develop pancreatic cancer after a daily healthy breakfast (five) compared with a bacon sandwich (six), the difference doesn't look very impressive (see far right).

"I would argue that there is no 'true risk' in the sense that these chances and values actually exist as part of the outside world – they are constructed on the basis of our judgement and knowledge."

I have been collaborating with Dr Mike Aitken in the Department of Experimental Psychology on the Big Risk Test run by BBC Lab UK, in which over 60,000 participants have taken part in an online randomised trial of different formats and images. The insights gained are being used to help design revised patient information leaflets and websites for a cancer screening programme in the UK.

But in many situations there is deeper uncertainty, and we are rightly not so happy to give concrete numbers to risks. The National Risk Register (see panel) gives wide intervals for the chances of various disasters occurring, while the Intergovernmental Panel on Climate Change and other organisations have developed measures of 'confidence' or star ratings for their risk analyses. The UK government officially encourages the acknowledgement of such scientific uncertainty, but can we retain trust if we are so open?

Fortunately there are signs that these issues are being taken seriously, with the House of Commons Select Committee for Science and Technology recently recommending a Risk Communication Strategy Group across government. But a problem is that this area cuts across many academic boundaries, and there is little focused infrastructure in the UK. Risk communication is a topic that deserves investment in research and training.



Approximate number of people developing pancreatic cancer in their lifetime out of 400 people whose daily breakfast is either healthy (top) or a bacon sandwich (bottom)

The making of a National Risk Register

Why does Britain need a National Risk Register (NRR)? To understand what the risks are and how to improve resilience, explains John Tesh, the Cabinet Office official responsible for the NRR and Fellow of Cambridge's Centre for Science and Policy.

This is not a particularly disaster-prone country when compared with other countries. After the Cold War, the British approach to what seemed like a rather modest risk landscape emphasised improvisation. Until, that is, the 2000 and 2001 emergencies – foot and mouth disease, fuel strike, flooding – and the aftermath of the 9/11 attacks, which suggested that 'muddling through' would no longer do. The government had to show that it understood what the risks were and how best to organise to improve resilience.

Which is why, since 2004, British governments have based planning for domestic emergencies on a national risk assessment that ranks the risks according to likelihood and impact. First published in 2008, the NRR was updated in 2010 and 2012. Risk management approaches are increasingly being used to plan for events – for the Olympic Games as an example – and for national security in general.

A risk management strategy provides the best approach to making informed decisions on the necessary investments in resilience. It enables us to avoid attempting to predict future shocks in an inherently unpredictable risk landscape. Risks can be prioritised, and the highest risks identified – currently, pandemics, coastal flooding, mass killings by terrorists and gas-rich volcanic eruptions – to enable special programmes of mitigation to reduce vulnerabilities to such risks by preventing, preparing for, responding to and recovering from them.

In a time of unprecedented resource constraint, it is essential to be able to prioritise planning to make sure that help goes where it can do the most good. Identifying and planning for the common consequences of risks, irrespective of source, also helps prevent wasteful duplication and can aid business continuity and recovery.

If having clear objectives has been the secret to effective risk management strategy in the past few years, the key for the future will be a balanced collaboration between science and policy. This was the main finding of the House of Commons Select Committee for Science and Technology in its work on the use of science for emergency planning and crisis management. We are taking this seriously: the national risk assessment process includes reinforced mechanisms for independent cross-disciplinary scientific advice.

University of Cambridge scientists are already working on some of the risks that pose the greatest challenge for risk assessment, where particular uncertainties attach to calculations of probability or impact or both… and where significant investment in resilience of national infrastructure and public safety hangs in part on getting the answer right, or at least good enough for government work.

For a longer version of this article, please visit www.cam.ac.uk/research

Professor David Spiegelhalter

For more information, please contact Professor Spiegelhalter (david@statslab.cam.ac.uk), or visit the Winton Programme for the Public Understanding of Risk (understandinguncertainty.org).

Threats that cause supply chains and other networks to break down can cascade through today's interconnected world of social, economic and financial interaction. New research is redefining this global risk to help businesses and governments build resilience.

Crash, crisis, calamity: system shock in a globalised world

Global supply chains like those that underpin car manufacturing can be affected by threats such as natural catastrophes, conflicts, disease outbreaks and trade disputes

Many of us will never have heard of PA-12. But when an explosion in a factory in Germany on 31 March 2012 halved its global source, this little-known component of car fuel lines gained notoriety by threatening production in the automotive industry. It's a scenario that had already been played out twice in the preceding year when specialised automotive parts became scarce following the Tohoku earthquake and tsunami in Japan, and following a factory fire in the USA.

The tale of PA-12 demonstrates the fragility of global supply chains but is not altogether a surprise. Businesses understand the risks inherent in globalised supply chains that might be affected by natural catastrophes, geopolitical conflicts, disease outbreaks, trade disputes and so on. But what might be less obvious is how interconnected are the networks of relationships of trade, business and macro-economics, and how quickly the effects of a catastrophe can cascade.

"It used to be the case that catastrophes on the other side of the world had little economic impact on the UK," explained Dr Andrew Coburn, researcher in the Centre for Risk Studies at Cambridge Judge Business School, "but in today's interconnected world, few countries are isolated from the knock-on effects of catastrophes, whether it's a freeze in Europe, piracy around the Horn of Africa or a pandemic in Asia."

Coburn is also Senior Vice President at Risk Management Solutions (RMS), the leading provider of catastrophe risk models to the insurance industry. By modelling risk to extreme events, he has provided research inputs into government policy on disaster mitigation and terrorism risk management policy. Now, a research programme that he leads at the University of Cambridge aims to provide new understanding of how socioeconomic risks (or 'system shock') can not only damage supply chains but also disrupt the networks that keep our lives going.

The programme, which is funded by Deloitte, the Institute of Catastrophe Risk Management at Singapore's Nanyang Technological University and RMS, has taken the ambitious step of combining catastrophe science with systems analysis. It's a challenging but high-gain move, as Coburn explained: "This is a very new area. Catastrophe science is a multi-billion dollar industry that's been around for a few decades, but putting it together with network analysis has not been done before. We are having to start with the nuts and bolts and develop a new methodology."

Part of this methodology, developed in collaboration with Nanyang Technological University, has been to derive a list of threats. Working with colleagues at Cambridge's Centre for Financial History, the researchers have taken a remarkably long historical perspective, as Research Associate Dr Gary Bowman explained: "Analysing events from only the recent past can paint quite a misleading picture. We're taking a 1,000-year perspective that allows us to be much more rigorous in terms of assessing the frequency of events and the resulting effect. In fact some of the best examples of threats such as asset crashes can be found in the 17th and 18th centuries – in the Amsterdam Tulip bubble and the South Sea bubble for instance."

Recent shocks to the system

Although the taxonomy of threats developed by the research project has taken a 1,000-year look back through history, an example of many of the types of threats has happened in recent years:

- Political violence: Arab Spring 2011
- Natural catastrophe: earthquake and tsunami, Tohoku, Japan 2011
- Technological catastrophe: nuclear meltdown, Fukushima Daiichi, Japan 2011
- Geopolitical conflict: civil war, Libya 2011
- Humanitarian crisis: Horn of Africa drought 2011
- Climatic crisis: heatwave, USA 2011
- Financial shock: Greek sovereign debt crisis 2010
- Environmental catastrophe: BP Oil Spill Deepwater Horizon 2010
- Trade dispute: US tax on Chinese tyres 2009 reciprocated by Chinese tax on US chicken imports
- Disease outbreak: swine flu pandemic 2009

The result is a systematic taxonomy of socioeconomic threats that could conceivably threaten human and financial capital, damage assets and disrupt the systems that support our society, at either a national or an international level.

With the help of a peer review process involving risk professionals, academics and corporate advisory groups, the researchers have captured 12 broad types (broken down into 47 subclasses) of the most significant threats that could interrupt a major region's normal life patterns, wipe more than 1% of a country's GDP, or, where applicable, kill more than 1,000 people or cause a loss of assets or infrastructure amounting to $10 billion.

Over time, the Centre for Risk Studies plans to expand their research website (systemshock.org.uk) to provide state-of-knowledge illustrative scenarios for each of the 47 subclasses of threat; already five are in preparation. The scenarios are objective, transparent, evidence-based, useful in business decisions and available to the risk management community.

"For piracy, for instance, we are reviewing all of the instances of piracy in the Horn of Africa and factoring in the cost to shipping," explained Bowman. "We'll then ask at what point does the threat become so significant that the system starts to adapt – shipping lanes change or a military presence protects commerce in the region."

In parallel, for each scenario, Professor Danny Ralph is coordinating research on what system shock means for the automotive, pharmaceutical and electronic industries, each of which has a highly interconnected global network: "Where we think we can add value is to take what businesses understand well – their markets, components and contractors – and set alongside it a higher level framework of system shock."

The System Shock project is part of the Cambridge Risk Framework research project at the Centre for Risk Studies, a multi-disciplinary centre for the study of societal and economic risks. "We believe the Centre has a unique opportunity for studying global risk strategies and their impacts to businesses and governments," added Michelle Tuveson, the Centre's Founder and Executive Director. "Although often perceived narrowly, we view 'risk' as a broad topic. It has far-reaching implications particularly to culture, governance and decision making."

Ralph, like his colleagues, admits that much work on System Shock lies ahead: "It's like looking at an *Encyclopaedia Britannica* that's been written but hasn't been assembled. At the least, this task will help these industries visualise, categorise and discuss their broader risks. But the greatest challenge of all will be to reach the stage when businesses and governments can plug in real-world data to help them quantify and make decisions about future investments or current configurations of supply chains."

The researchers are also interested in how the management of risk relates to national systems: how the nation's food or fuel supply networks function and how they can be more resilient to threat. "None of us has a crystal ball and all of us are going to be subject to continued pressures. There is no magic wand. But if you think about the risks and opportunities an organisation or a country faces, you have to take a holistic view because your network is integrated in obvious and less obvious ways with other networks," said Ralph.

Simon Ruffle, Director of Technology Research in the Centre, has begun the task of building the computer infrastructure that will store the taxonomy, illustrative scenarios and data. "Part of this will involve electronic collaboration with databases around the world that can provide historical and up-to-date information on global air routes, sea lanes, communications, environmental changes and so on," he explained.

"Can this project redefine how we think about risk globally?" asked Coburn. "We hope so – we think that considering risk as a network problem is the way forward. To think about it as a threat issue is misleading. You have to understand all of the complex connections to be able to really understand risk."

"This is a very new area. Catastrophe science is a multi-billion dollar industry that's been around for a few decades, but putting it together with network analysis has not been done before."

Left to right, Simon Ruffle, Dr Andrew Coburn, Dr Gary Bowman, Professor Danny Ralph, Michelle Tuveson

For more information, please contact Professor Ralph (d.ralph@jbs.cam.ac.uk) at the Centre for Risk Studies at Judge Business School or visit systemshock.org.uk

Ounce of prevention, pound of cure

Working with humanitarian organisations in Haiti, Cambridge researchers have found that an information system they designed to track how regions recovered from disasters can also be used to support preparedness, planning and project management.

Benjamin Franklin famously advised fire-threatened Philadelphians in 1736 that "An ounce of prevention is worth a pound of cure." Clearly, preventing fires is better than fighting them, but to what extent can we protect ourselves from natural disasters? Hazards such as earthquakes, tsunamis, floods, hurricanes and volcanic eruptions are not in themselves preventable, but some of their devastating effects could be reduced through forward planning.

"It's important to be able to recover resiliently from disasters and, as part of this, it's vital to identify the vulnerabilities of communities living in hazard-prone regions," explained Michael Ramage from the Centre for Risk in the Built Environment (CURBE). By putting resources into resilience and building back better, communities can reduce the risk of disastrous consequences should a similar event reoccur."

Now, thanks to an information system that Cambridge researchers developed originally for tracking how regions recover from disasters, communities could soon have the means to understand how best to protect themselves from future catastrophes.

The story begins in Haiti, where CURBE researcher Daniel Brown has been working over the past year with the British Red Cross and the United Nations following the devastating earthquake in 2010, which killed 316,000, displaced 1.3 million and destroyed almost 100,000 houses. In a country that was deeply impoverished before the earthquake, people continue to live under tarpaulins exposed to safety and security risks, with limited access to water, livelihoods and key services.

Brown travelled to the country to field-test a system that he and colleagues at Cambridge Architectural Research (CAR) and ImageCat had developed during the previous four years as a mapping technique for tracking post-disaster recovery.

With funding from the Engineering and Physical Sciences Research Council (EPSRC), Brown had identified a suite of 12 'performance indicators' spanning core recovery sectors extracted from high-resolution satellite imagery. He used these to map the recovery process in Ban Nam Khem, Thailand, after the 2004 Indian Ocean tsunami, and Muzaffarabad, Pakistan, after the 2005 Kashmir earthquake, by looking at aspects such as the movement of populations, the construction of dwellings, the accessibility of roads, and the loss and rebuilding of livelihoods.

In Thailand and Pakistan, the system had already proved to be extremely useful. Brown's work provided data and results that assisted decision making and had the potential to ensure the recovery process was both transparent and accountable.

In Haiti, the EPSRC-funded follow-on project aimed to fine-tune the performance indicators within operational situations to suit the workflow of aid agencies.

What Brown found, however, was that in the complex and dynamic situation that follows a disaster, agencies desperately needed a real-time system to help them decide where to put resources. "Many of the hundreds of maps produced within the first week of the Haiti earthquake were soon out of date because of the changeability of the situation," he explained. "There was also a massive duplication of effort, with agencies often lacking trained staff to ensure the right information about buildings and people was acquired at the right time."

Dr Stephen Platt, Chairman of CAR, who has also been working on the project, described how these findings confirmed the results of a survey the team had previously carried out: "Agencies told us that they lack coordinated mapping information on where displaced populations have gone and where they have begun to return to, as well as damage to livelihoods, and rehabilitation of homes and infrastructure. It's very hard for them to decide where to put funds to the best effect for positive and resilient change."

Brown's first task was a remote analysis of the affected area from his office in Cambridge, using pre-disaster satellite imagery together with a new technique based on high-resolution oblique aerial

COLIN CROWLEY ON FLICKR

Aftermath of the 7.0-magnitude earthquake that struck Haiti in January 2010

Earthquakes without frontiers

Just as better rebuilding is important for mitigating repeat natural disasters, so too is understanding the threat posed by unanticipated earthquakes – now the focus of a new study led by the University of Cambridge.

A new five-year study is to target a neglected area of earthquake research – the 10 million km^2 of the Alpine–Himalayan belt stretching from Italy, Greece and Turkey, across the Middle East, Iran and central Asia, to China. Earthquakes in continental interiors such as these lead to significantly more deaths than those on the better-studied plate boundaries because they often take place on unknown faults.

The £3.5 million 'Earthquakes without frontiers' project will not only pinpoint faults in the Earth's crust but will also understand the vulnerabilities of communities at risk and communicate this knowledge to policy makers. Led by Professor James Jackson from Cambridge's Department of Earth Sciences, the study involves physical and social scientists from six UK universities and four institutes and organisations, together with collaborators in some of the most earthquake-prone regions of the world.

An important feature of the work, which is funded by the Natural Environment Research Council and the Economic and Social Research Council, is to build multinational collaborations that span entire regions and connect scientists working in affected areas with a larger international community of scientists.

For a longer version of this article, please visit www.cam.ac.uk/research/news/earthquakes-without-frontiers

photographs that capture views of the façade of buildings, and Lidar, which measures building height. On his arrival in Haiti, he identified which of the performance indicators was relevant for planning and used these to gather field information on the state of buildings, the socioeconomic impact on people, the safest places to rebuild and the community's views. All data were integrated into a single database to aid the design of a rebuilding programme.

"We were delighted to find that the information system can be used for all phases of the disaster cycle, from preparedness through to damage assessment, then planning and finally recovery monitoring. You could think of each phase comprising a single module in the database. All these phases are effectively interrelated with each other – data produced during one phase can be used in another phase. So when we collected damage data, these could be used as a baseline to inform planning, and so on," explained Brown.

Ramage, Principal Investigator for the follow-on project, added: "You can see how a system that can be used to predict where future vulnerabilities might be in a community is so important. And, through Steve's work in New Zealand, Chile and Italy, we have learnt more about how governments and agencies in developed countries are currently responding to disasters, which has allowed us to learn more about how our system and ideas might be adapted for different contexts."

Echoing this, Dr Emily So, Director of CURBE, explained how the project fitted into what's been called the disaster management cycle: "Governments and agencies think in terms of mitigation, preparedness, response and recovery. What we are trying to do in our research – which builds on 25 years of work in this area in the Department of Architecture under the leadership of Professor Robin Spence – is to make sure that we not only do reactive groundwork after the disaster but also proactive work, to mitigate and prepare ahead of the event and reduce the risk of disaster."

The team has recently been awarded funding for a two-year project involving eight global institutions with the remit of using satellite remote sensing to understand risk and vulnerabilities in communities around the world, under the European Commission's Seventh Framework Programme.

"The hazard itself is not what creates the disaster," added So. "It's the quality of the housing and the social fabric. This is where CURBE can help in terms of assessing exposure and proposing methods of evaluating it. Better information means better ideas, means better protection."

"Better information means better ideas, means better protection."

Top: Dr Emily So, Dr Stephen Platt; bottom: Michael Ramage, Daniel Brown

For more information, please contact Dr So (ekms2@cam.ac.uk), Director of the Centre for Risk in the Built Environment, which is an interdisciplinary research centre involving the Departments of Architecture, Engineering, Geography, and Public Health and Primary Care.

Privacy by design

New research aims to ensure that we can exploit the full benefits of the digital world and still protect our online privacy.

Online services that store our personal information have proliferated, yet the technology to underpin how our privacy is safeguarded has lagged behind. This was the conclusion of a 2008 report by the UK's Information Commissioner's Office, a body set up to uphold privacy for individuals, which pressed for "the evolution of a new approach to the management of personal information that ingrains privacy principles into every part of every system in every organisation."

This ethos underpins research led by Professor Jon Crowcroft, the Marconi Professor of Communications Systems in the Computer Laboratory. Two projects he leads aim to minimise privacy risks, and at the heart of both is the concept of 'privacy by design'.

"Privacy by design means that it's in-built as part of the technology, rather than bolted on in order to comply with data protection laws," he explained. "With privacy by design, it would simply not be possible for incidents such as the leaking of LinkedIn passwords to happen."

One project is tackling the challenge of how to maintain privacy when all your data are stored by a central service – the so-called cloud. Anyone who stores images on flickr, or accesses emails from a central server, is cloud computing, and today many businesses are turning to centralised data centres as an economic means of storing their information. However, concerns have also been raised about the scale of control that cloud service providers wield over the data they store and can potentially monitor.

Crowcroft and colleague Dr Anil Madhavapeddy are building technologies to support the control of networked personal data as part of a five-year £12 million research hub ('Horizon'), which is led by the University of Nottingham and funded by the Engineering and Physical Sciences Research Council (EPSRC). The research is driven by the overarching concept of a lifelong contextual footprint – the idea that each of us throughout our lifetime will lay down a digital trail that captures our patterns of interaction with digital services – and how best to protect this.

A second project, FRESNEL (for 'Federated Secure Sensor Network Laboratory'), is focusing on privacy in networks that people use to modify their heating, lighting and home entertainment when they are not at home, as well as networks that monitor traffic flow and air quality, and enable a doctor in hospital to check a patient's health at home.

"Current technologies have usually been devised for single-owner sensor networks that are deployed and managed by a central controlling entity, usually a company that has set themselves up to offer this capability," he said. "They don't have the right scalability and security required to deal with a secure multi-purpose federated sensor network, running different applications in parallel. Our aim is to build a network framework with multiple applications sharing the same resources."

With funding from EPSRC, Crowcroft and Dr Cecilia Mascolo and colleagues, working with Dr Ian Brown at the University of Oxford and industrial project partners, now have a demonstrator program in operation that is currently being evaluated through a large-scale federation of sensor networks across the University of Cambridge.

The aim of these projects, explained Crowcroft, is not to lock up personal data, removing the ability to socialise it, but rather to support systems that process data without sacrificing privacy: "We are building technologies to support lifelong control of networked personal data. For instance, a significant driver behind social networking has been the ecosystem of data processors that aggregate and provide services such as recommendations, location searches or messaging. But the big drawback is that users have to divulge more of their personal data to a third party than is necessary, because of the difficulty of distinguishing what is needed. Our research starts from a single premise – that individuals require control over access to, and use of, their personal data for ever."

Left to right, Professor Jon Crowcroft, Dr Cecilia Mascolo, Dr Anil Madhavapeddy

For more information, please contact Professor Crowcroft (jon.crowcroft@cl.cam.ac.uk) at the Computer Laboratory (www.cl.cam.ac.uk).

Crowcroft and colleagues have launched a not-for-profit foundation, Digital Life Foundation (http://dlfn.org), which will build an open-source community around these technologies.

Cybercrime economics

As the internet becomes bigger and more complex, so do the opportunities for cybercrime. Where should resources be directed to combat the risk?

In the 'good old days' of cybercrime, online misdemeanours were mostly the work of teenage hackers or small-scale crooks with a card-coding machine. Now, however, PIN numbers are harvested in industrial quantities, and criminal networks of 'phishermen', 'botnet herders' and writers of malicious software are costing society billions of dollars every year.

Online crime is a sophisticated and efficient business, involving tax and credit card fraud, fake antivirus, unlicensed Viagra and 'stranded traveller' scams. 'Phishing' emails may appear to be from your bank but are designed to steal your identity. 'Botnet herders' take over your computer as one of many 'bots' and use it to send out email spam.

The police and courts are struggling to catch up, as Professor Ross Anderson explained: "Thus far, the world has not coped well with the rapid growth and industrialisation of online wickedness. Banks often hide fraud losses, or even blame their customers for fraud, and they hesitate to share information with other banks. Police agencies have little idea how to deal with industrial-scale globalised petty crime."

His team of researchers work on high-tech computer security mechanisms and also study how and why internet security fails. In 2008, they reported to the European Commission on how governments can push back on cybercrime, identifying an increase in consumer protection as key to the process.

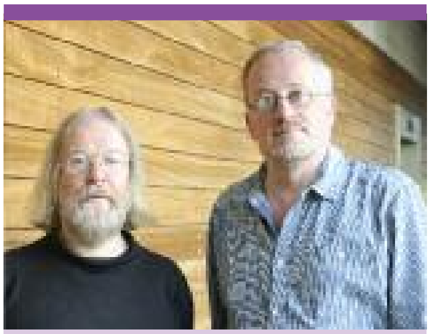
However, most governments still don't understand the true costs of cybercrime: "Hard statistics on losses from online crime are hard to come by in most countries. But without them, other figures – vulnerabilities in computer systems, number of botnets or size of spam flows – lack a grounded connection to the real economy," said Anderson, who is Professor of Security Engineering in the Computer Laboratory.

A recent study by Anderson, Dr Richard Clayton and colleagues completed the first systematic measure of the cost of cybercrime for the UK and the world. It found that fraud within the welfare and tax systems – increasingly performed in the 'cyber' world – cost each citizen a few hundred pounds a year on average, and fraud associated with payment cards and online banking cost just a few tens of pounds a year. However, the fear of fraud by businesses and consumers is leading some to avoid online transactions, giving an indirect cost to the economy that is several times higher. By contrast, pure cybercrimes – the new scams that completely depend on the internet – are costing citizens an average of only a few tens of pence per year.

Another interesting and unexpected finding concerned the ratio of direct costs (the money stolen) to indirect costs (the money spent on preventing crime, and on compensating victims or prosecuting perpetrators afterwards). In traditional frauds like tax and welfare fiddles, the direct costs are much larger than the indirect ones; with pure cybercrimes, the indirect costs are much larger; and with card fraud, they're about equal. These differences, explained Anderson, reflect the maturity of our technical countermeasures, the incentives for fraud prevention and the social norms that also push back on crime.

Overall, the team of researchers from Germany, the Netherlands, USA and UK found that although cybercriminals are pulling in a few tens of pounds from every citizen per year, the indirect costs to those citizens, either in protective measures such as antivirus or in cleaning up infected PCs, are at least ten times as much.

They conclude that we should spend less on defence and more on policing, as Anderson explained: "The number of phishing websites, distinct attackers and different types of malware is consistently overreported, leading some police forces to believe that the problem is too large to tackle. In fact, a small number of gangs lie behind many incidents and a police response against them would be far more effective than telling the public to fit an anti-phishing toolbar or purchase antivirus software. Cybercrooks impose disproportionate costs on society and yet we are extremely inefficient at fighting cybercrime."



Dr Richard Clayton (left) and Professor Ross Anderson

For more information, please contact Professor Anderson (ross.anderson@cl.cam.ac.uk) at the Computer Laboratory (www.cl.cam.ac.uk).

The future of flying

Aircraft that work together to solve complicated mathematical problems and airports with more flexibly used runways could be the future of flying, according to studies by University of Cambridge engineers and their industrial and academic partners.

Air traffic across Europe is likely to double by 2020 according to current forecasts. This estimated increase represents a remarkable number of flights when you consider that last year in the UK alone almost 2.2 million flights carrying 200 million passengers were handled by the National Air Traffic Services.

It also represents a massive challenge for UK aviation policy, which is faced with airports operating at near full capacity such as Heathrow – the busiest in the UK and one of the busiest in the world. Increased air traffic, rising fuel prices and tight security all combine to increase the vulnerability to system-wide breakdowns, delayed flights, long queues and rising costs.

Efforts to reduce pressure on overstretched airport facilities are being aided by research projects involving University of Cambridge engineers working with industrial and academic partners. Each project is aimed at tackling some of the uncertainties associated with air traffic, and the risks these pose to heavily loaded airports, wherein even a short delay finding a wheelchair for a passenger with reduced mobility can affect the tight workings of the airport.

Database in the sky

One limiting factor in dealing with a vastly increased air traffic density is the workload falling on air traffic management (ATM). "Some of the technologies assisting ATM date from the 1950s," explained Professor Jan Maciejowski, who led the University of Cambridge component of a recently completed pan-European study, iFly. "We've been looking at how we can modernise and automate ATM to improve safety at the same time as reducing workload, costs and environmental impact."

The project, funded by the European Commission and coordinated by the National Aerospace Laboratory in the Netherlands, brought together 17 partners from academia and aerospace industries across Europe. Their mission was to develop an advanced airborne flight information system so that processes normally carried out on the ground by air traffic controllers can be carried out mid-flight by multiple aircraft requiring the same airspace.

"Essentially the idea is for the aircraft to use onboard computers to predict future positions of other aircraft and to dynamically share information," explained Maciejowski, who worked on the project with PhD student Ellie Siva and colleagues at the Swiss Federal Institute of Technology Zürich and the National Technical University of Athens. "The computers communicate with each other, negotiating how best to use the airspace with least cost in terms of fuel and time, while respecting the priorities of other aircraft and the comfort of passengers, and of course maintaining safe separation from each other."

The automated system enables different aircraft to solve complex mathematical optimisation problems between them – each one solving the problem for itself and then passing on its current solution and intentions to the next aircraft, which then responds, and so on. In a simulation of about 1,000 flights, the researchers found that this cooperative activity results in only a very small extra distance being flown (less than 1%) per aircraft.

Ultimately, the hope is that if such a system came into operation, it would accommodate a three-to-six fold increase in current en-route traffic levels and be part of a System Wide Information Management 'database in the sky' proposed across Europe.

At the heart of the project is the discipline of control engineering. A recent

JOHN WOOD ON FLICKR

Heathrow airport

"I've been delighted by how positively airport operators have reacted already. It's a sign of the times – airports are running at capacity and it's becoming a matter of urgency to look at how systems can be improved."

programme grant awarded to the University of Cambridge and Imperial College London by the Engineering and Physical Sciences Research Council has assembled a team to push the boundaries of control engineering in relation to power systems and transportation. As part of the programme, Maciejowski is looking at another aspect of air traffic control – the terminal manoeuvring area between the airport and 10,000 feet up.

Here, a very different scenario is in operation: many aircraft in a small space require coordination to land using the least amount of fuel, a situation too complicated to solve by aircraft communicating with each other. Maciejowski and colleague Dr Alison Eele are creating a new mathematical system to optimise the landing trajectories of each plane. Their formulae use thousands of processors, now economically available as graphical processor units, to combine location measurements by radar, work out the flight plan for landing, give instructions and then recalculate every few seconds.

Although both projects are a long way from implementation – they would first need to go through rigorous safety checks in collaboration with airlines and authorities – Maciejowski explained that each has now reached a proof-of-concept stage and initial talks have begun: "I've been delighted by how positively airport operators have reacted already. It's a sign of the times – airports are running at capacity and it's becoming a matter of urgency to look at how systems can be improved."

Flexible working

Meanwhile, the focus of Professor Duncan McFarlane's research is what happens on the ground. Working with Alan Thorne and other colleagues at the University's Institute for Manufacturing (IfM), the team is involved in trials conducted by BAA at Heathrow Airport on measures to increase punctuality, reduce delays and strengthen resilience at the UK's hub airport. The trials are centred on making the best use of the airport's two runways, which are in heavy demand.

In the first phase of the Operational Freedoms trial, which was completed in February 2012, Heathrow explored how its runways and airspace can be better used to recover quickly following airport disruption, such as that caused by bad weather. One strategy was to use both runways for either arrivals or for departures, instead of one for each. Initial results indicated improvements in punctuality, reduced emissions and fewer planes having to taxi across runways. A second phase is now ongoing until March 2013 to carry out a more-detailed analysis.

"The Civil Aviation Authority is overseeing the tests. Our role has been to independently audit the trial and ensure its objectives are met," explained McFarlane. "We measure everything to do with the impact of changes on the performance of the airport, from how long the aircraft are in overhead 'circulation stacks', to take-off delays, to emissions and noise, and then we generate what we think are appropriate recommendations."

A further study has also just started, this time examining the order of aircraft landing on runways. "A big aircraft creates a huge air turbulence behind it and small aircraft have to wait proportionally longer before landing," said McFarlane. "Flexible use of runways could mean landing larger aircraft on one and smaller on another, or ordering planes in overhead circulation stacks into optimal landing sequences. Using runways effectively could go a long way towards helping airport operations recover quickly and efficiently from unwanted variability."

The current studies build on a major aerospace programme at the IfM driven by the end users of the research – the aircraft manufacturers, airlines and airports. For instance, the researchers have previously examined how radio-frequency identification (RFID) technology and better data sharing in airports can reduce costs and achieve greater business efficiencies.

Many of the delays in airports occur as a result of bottlenecks in the sequence of activities that take place when an aircraft is at a gate between flights. Referred to as the turnaround process, the operation involves the coordination of activities such as baggage handling, refuelling, maintenance tasks and passenger transfer. Because the companies carrying out these tasks don't always share information, a breakdown somewhere along the line can cause a system-wide snarl-up.

Tiny electronic RFID tags can be used to provide visibility for different assets used in airport operations, such as bags, baggage containers and catering trolleys, which can then be fed back to computers used by the different service teams on the ground, allowing them to recognise and share problems quickly.

Working with airlines such as Easyjet and FlyBe, and Manchester, Luton and Heathrow Airports, the researchers looked at what causes delays and whether better information usage can improve aircraft turnaround time. "For example, one cause of aircraft delay can be the unavailability of a wheelchair to take a passenger to a flight. Something as simple as a strategy for locating and ensuring wheelchairs are in the right place at the right time can make a considerable difference to guarding against delays," explained McFarlane. "What our aerospace programme is trying to do is quantify the risk and uncertainty associated with different disruptions, and then redesign and pilot robust practices that will eliminate unexpected delays or increased costs."

Professor Duncan McFarlane (left) and Professor Jan Maciejowski

For more information, please contact Professor Maciejowski (jmm@eng.cam.ac.uk) at the Department of Engineering (www.eng.cam.ac.uk) and Professor McFarlane (dcm@eng.cam.ac.uk) at the IfM (www.ifm.eng.cam.ac.uk).

Apocalyptic thinking and urban resilience

Through analysis of human resilience, particularly in cities, Professor Ash Amin believes that state guarantees of welfare and infrastructure will prove vital for our future – a view that is counter to much of the West's current policy emphasis on the responsibility of the 'individual' in a turbulent age.

NEUEWEIDE ON FLICKR

As global boundaries continue to crumble in the face of technological advance, the proliferation of possible threats has become overwhelming. The effects of climate change, rogue behaviour, financial swings and pandemics will amplify and take unexpected courses in this century's complex and interdependent world.

Ash Amin, the 1931 Professor of Geography, believes that this uncertainty has fostered a new rhetoric of risk management, describing a future where we must become 'resilient' individuals. We are told that we can no longer expect to rely on our governments; we need to be vigilant and 'prepared' ourselves.

"This kind of shift is accompanied by a return to fatalist or apocalyptic thinking – public narratives of an out-of-control future," said Amin, author of the recently published book *Land of Strangers* (2012), which examines the challenges of living with difference in Western multicultural societies that perceive the future as uncertain and turbulent. "In the late 20th century, there was a conviction that science and calculation combined with central planning allowed for future preparations."

"Now, in the West, you have a public that is more informed but more sceptical, isolated and paranoid, and fed by a hyperactive media. The result is a potentially destructive mixture of mistrust, resignation and expectancy."

Every step taken by states to develop new vaccines, secure borders and so on is accompanied by public campaigns that deliberately dampen expectations of their effectiveness. We are constantly made aware that comprehensive security no longer applies.

"Innate in a new culture of risk management by resilience is a cataloguing of risk-bearing subjects, so that management of our unknown future can be given tangible shape – vigilance against named subjects," he explained.

"Catastrophism in a post-9/11 world has quickly turned towards vilification of particular humans – such as asylum seekers, the Occupy movement, Muslims, angry youth. It's part of an active pathology of risk management, often hiding bureaucratic bewilderment in the face of escalating global risks."

Such a shift in the calculus of control – from institutions to individuals, from protectionism to preparedness – has important urban implications. The Planet's vast metropolises continue to swell as population increases, with millions migrating to the cities to find work in an economically precarious world. By 2030, at least 70% of the global population will be living in urban environments, with up to 2 billion dwelling in slums.

"I am an urbanist – I study cities – and urban resilience is central to our collective futures," said Amin. "To speak of citizen subjectivity – the 'resilient' individual – in the context of those living in abject poverty is absurd. We need a return to language of protection, so that the poor are given some of the basic infrastructure to deal with risk."

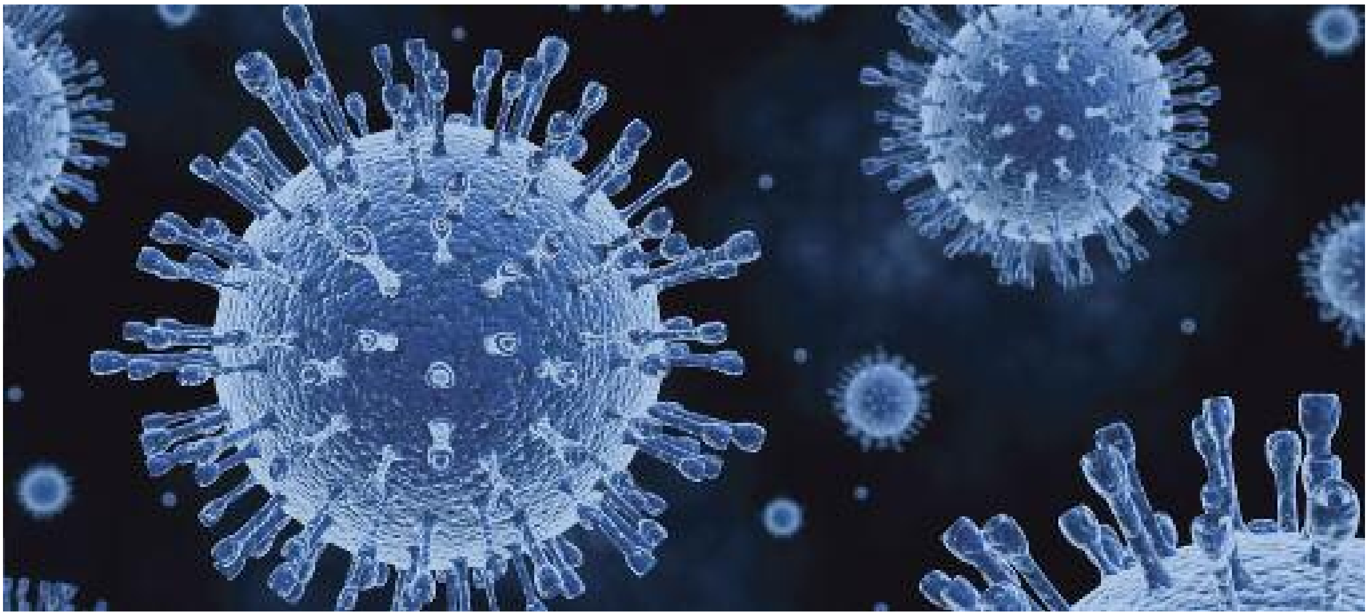
"In the West especially, we still live in a society where people expect protection to be provided by someone else – but that requires resources."

Amin uses Sweden as an example of a state that invests heavily in risk management, so that in the event of a catastrophe there is sufficient slack in the system of emergency services and welfare provision, allowing rapid recovery. But this requires a different form of social contract, in which acceptance of higher taxes means that the public have a right to expect protection by the state.

For Amin, scaling back the state when preparing for a turbulent future seems dangerous. While individuals need to be vigilant, he warns against scapegoating particular subjects for the risks we face. "In the end, the capabilities of everyone will need to be harnessed in a responsible and democratic way to meet the myriad risks of the future. We can't leap into the dark with both guns loaded – shooting wildly at everything and anything – and hope to come out on top."

Professor Ash Amin

For more information, please contact Professor Amin (aha29@cam.ac.uk) at the Department of Geography (www.geog.cam.ac.uk).



Original sin and the risk of epidemics

Mathematicians are helping to build a better picture of how populations develop immunity to flu and which groups are most at risk of getting – and transmitting – infection each year.

The adage 'what doesn't kill you makes you stronger' may ring true for certain infectious diseases – those where repeated exposure to the pathogen progressively builds population immunity – but not for influenza. When scientists investigated age-specific immunity to influenza strains after the 2009 swine flu pandemic, a curious pattern emerged. Antibodies against seasonal flu appear to peak in school-age children, drop in middle age and rise again in the over 65s.

Now mathematicians in Cambridge have developed a model that explains this little-understood pattern, and in so-doing are helping to build a better picture of how flu might be controlled. At the heart of their model is the concept of 'original antigenic sin', a phenomenon first identified in the 1960s by American epidemiologist Thomas Francis that describes how the body's immune system, in effect, takes short cuts.

Rather than generating a specific antibody response every time a new pathogen is encountered, the immune system may instead reproduce a previous response to something similar (the 'original antigenic sin') it has seen before. What this means for immunity is that it's not just the infections we've had in the past but the order in which we've had them that could be important for how protected we are against a disease.

Dr Julia Gog and PhD student Adam Kucharski at the Department of Applied Mathematics and Theoretical Physics believe that the strikingly characteristic profile of immunity to influenza can be explained in these terms, and they've built a mathematical model to test it.

Understanding how immunity develops in a population is crucial for developing a robust public health defence, especially for a pathogen like pandemic influenza, which the UK government's latest National Risk Register has listed as the most likely risk to have the highest impact in the next five years.

Yet, modelling the dynamics of influenza on population immunity is no straightforward exercise, as Gog explained: "The evolving nature of the virus – necessitating an annual race to identify an appropriate vaccine – means that individuals can be exposed to many different strains over a lifetime. And for every new strain that appears, the number of possible infection histories a person could have had doubles. To build a model, mathematicians need to keep track of millions, if not billions, of possible combinations of infections."

According to Gog and Kucharski's model, the trick is to reconstruct the combinations of past exposures from the probabilities of having seen each particular strain. There is a catch, however. Individuals who have been exposed to one particular strain are more likely to have been exposed to other strains; this is because individuals who have previously been exposed are more likely to be old than young. The model therefore handles each age group separately: individuals who are the same age will have lived through the same series of epidemics, which means that past exposures will be independent.

Their model has enabled them to explain the distinctive pattern of age-specific immunity for flu. Immunity increases initially, peaking in school-age children, then decreases as previous exposures prevent new antibodies being made. Only when the strain evolves 'out of reach' of the original antigenic sin are new antibodies generated in later middle age. In the elderly, complete freedom from original antigenic sin, along with vaccination programmes, leads to another increase in immunity.

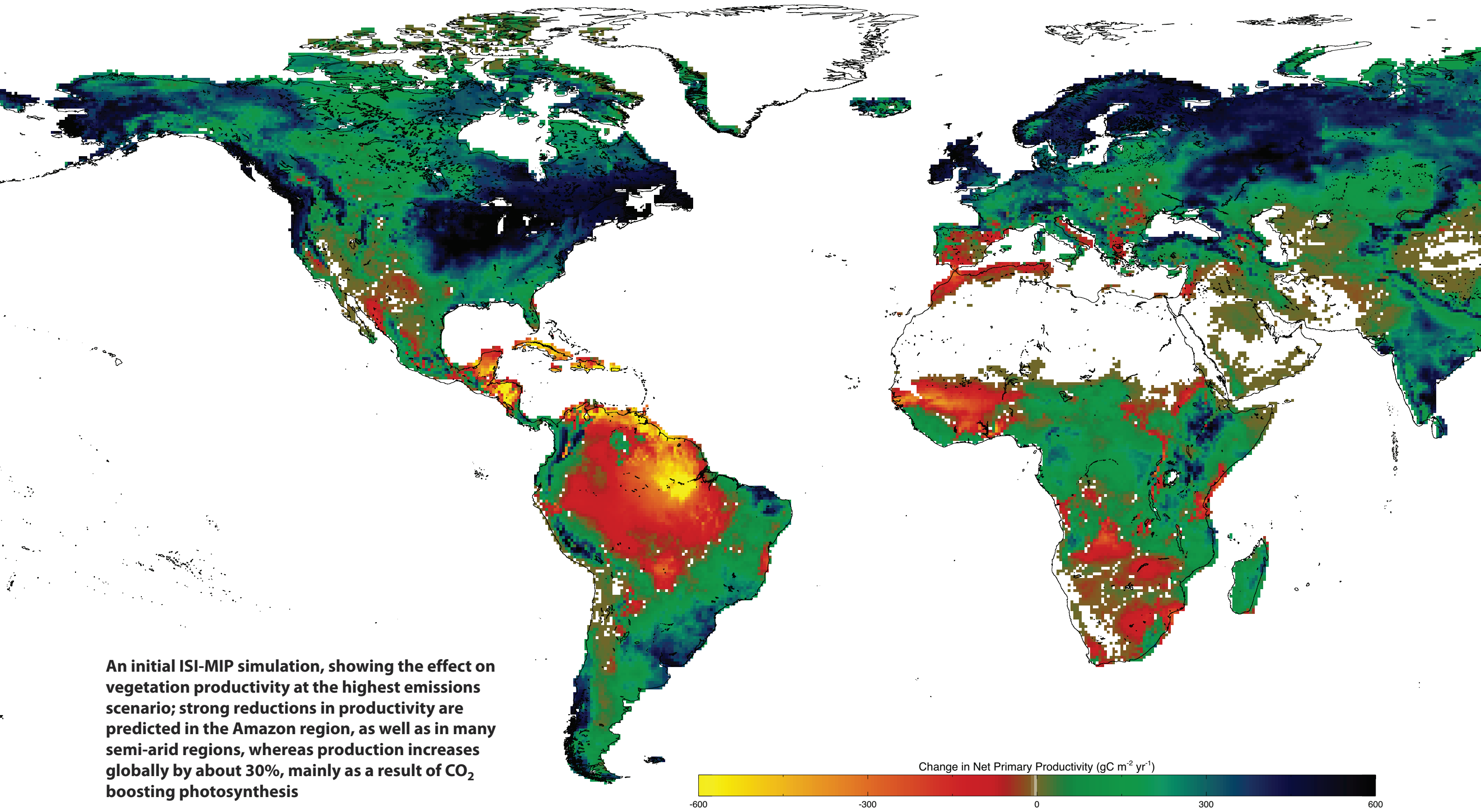
But what does this mean for disease control and identifying risk? "There could be gaps in immunity because less-effective immune responses are being generated as a result of original antigenic sin," explained Kucharski. "Over time, certain age groups may develop 'blind spots' in their antibody profile. We are building 'gap maps' to understand how often this happens. Moreover, the view that severe epidemics only arise when the virus has evolved significantly may be oversimplified. They could also arise if there are individuals whose immune response is ineffective because of original antigenic sin, which would explain why unassuming flu strains occasionally cause large outbreaks."

Adam Kucharski and Dr Julia Gog

For more information, please contact Dr Gog (jrg20@cam.ac.uk) at the Department of Applied Mathematics and Theoretical Physics (www.damtp.cam.ac.uk).

Modelling impacts of a warming world

A community-driven modelling effort aims to quantify one of the gravest of global uncertainties: the impact of global warming on the world's food, health, vegetation and water.



An initial ISI-MIP simulation, showing the effect on vegetation productivity at the highest emissions scenario; strong reductions in productivity are predicted in the Amazon region, as well as in many semi-arid regions, whereas production increases globally by about 30%, mainly as a result of CO_2 boosting photosynthesis

How different will the world be if it's 2°C, 3°C or 4°C warmer? Ask this question of the multitude of different climate change impact models – each built by researchers interested in different aspects of global warming – and the likelihood is that you will get a multitude of answers. Modelling the global impact of climate change is an extremely complex process, and yet it's absolutely essential if policy makers are to understand the consequences tomorrow of emissions policies adopted today.

Earlier this year, an international group of researchers initiated a joint project to attempt the first systematic quantification of some of the uncertainties surrounding climate change impacts to agriculture, health, biomes and water. Uncertainties such as: to what extent will the world's vegetation change? Which regions will succumb to drought or flood? What will be the impact on global food crops? And how will the spread of human diseases be affected?

The Inter-Sectoral Impact Model Intercomparison Project (ISI-MIP), coordinated by the Potsdam Institute for Climate Impact Research in Germany and the International Institute for Applied Systems Analysis in Austria, involves two-dozen research groups from eight countries. Dr Andrew Friend from Cambridge's Department of Geography is coordinating the analysis of results concerning changes to the world's biomes – the communities of plants, animals and soil organisms that are characterised by a similar structure and climatic requirement.

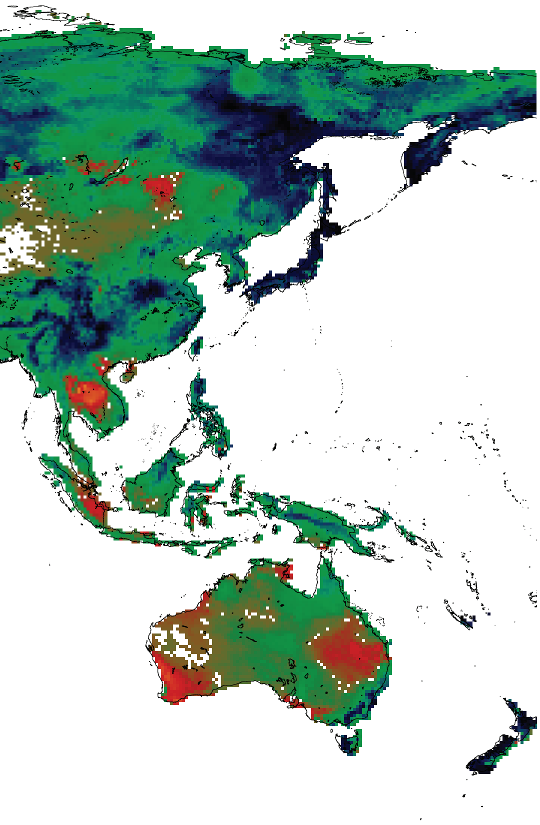
It's a fast-track programme. All of the teams are working to a tight deadline and, by January 2013, they hope to be ready to publish their findings on the likely impacts of climate change predictions. The collective results will contribute towards the next report of the Intergovernmental Panel on Climate Change (IPCC), the leading international body that provides a clear scientific view on the current state of knowledge in climate change and its potential environmental and socioeconomic impacts.

Each group is using their own model, together with the very latest climate predictions produced by leading climate modelling groups around the world, to run comparable simulations for four different warming scenarios – conservative, drastic and two in between – from 1950 to 2099.

For Friend, this means *Hybrid*, the model he first developed 15 years ago. At its heart is a set of equations that dynamically model global vegetation: "It works by simulating the dynamics of individual trees and an underlying herbaceous layer. You assume the plants compete within patches, and then scale these up to 50-km grid boxes. We use data to work out the mathematics of how the plant grows – how it photosynthesises, takes-up carbon and nitrogen, competes with other plants, and is affected by soil nutrients and water – and we do this for different vegetation types. Effectively, the whole of the land surface is understood in 2,500 km^2 portions. We then input real climate data up to the present and look at what might happen every 30 minutes to 2099."

For the most extreme scenario of climate change being modelled, Friend expects to see significant impact: "this scenario could show the whole of the Amazon rainforest disappearing this century, depending on the climate model. The circumpolar Boreal forest, which began to emerge at the end of the last ice age, could migrate into the tundra and perish at its southern limit. By contrast, Russia may benefit from an

> **"Each model has its own strengths and weaknesses. That's why the comparison process is so valuable – no single model is sufficient but together we can reduce the uncertainty."**



DR ANDREW FRIEND

Climate chemistry and the tropics

Just as global vegetation can be affected by a warming climate, the other side of the coin is true: changes in land use in the tropics could have unplanned side-effects on the Earth's atmosphere.

A team of atmospheric chemists at the Department of Chemistry are developing new models to predict how changes in land use in the tropics could affect future climate, air quality and crop production through their impact on ozone levels.

High in the stratosphere, ozone filters sunlight and protects us from the damaging effects of ultraviolet light. At ground level, however, it causes respiratory problems and damages crops. This ground-level ozone is formed by the reaction of sunlight on greenhouse gases emitted by cars, power stations and industrial processes. But it's also formed when volatile organic solvents (VOCs) emitted from plants react with nitrogen oxides (NOx).

"It's a complicated mechanism," explained Professor John Pyle, who leads the research. "In pristine conditions, such as in the tropical rainforests, VOCs can reduce ozone levels. However, in the presence of NOx, VOCs can increase ozone levels."

Research carried out in collaboration with Lancaster University demonstrated that the conversion of rainforest to oil palm plantations in Borneo substantially increased the local concentrations of VOCs and NOx. Modelling the effect on ozone, the researchers predicted that if NOx levels rise in the region as a result of industrialisation to the levels typical of North America and Europe, then ozone levels would exceed levels known to be harmful to human health and crop production.

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increased ability to grow crops in regions that were previously too cold, and this greater productivity would help absorb atmospheric carbon."

Modelling impacts is complex, as Friend explained: "the increase in CO_2 in the atmosphere from the burning of fossil fuels creates global warming. CO_2 can act on vegetation, increasing their rate of photosynthesis and therefore productivity. However, in heatwaves, ecosystems can emit more CO_2 than they absorb from the atmosphere. We saw this in the 2003 European heatwave when temperatures rose 6°C above mean temperatures and the amount of CO_2 produced was sufficient to reverse the effect of four years of net ecosystem carbon sequestration."

One of the greatest uncertainties in climate change is the feedback from changes in terrestrial carbon cycling. "Many scientists think that if soil warms it will release carbon because of the increased breakdown of dead organic matter by bacteria and fungi," added Friend. "But there's a lot of debate over whether this stimulation will be sustained over a long time – if it is, then you end up releasing enormous amounts of CO_2 into the atmosphere, causing further global warming."

Working with PhD student Rozenn Keribin, Friend is using Darwin, the University's High Performance Computing Service's supercomputer, to run the simulations; what takes a month to perform on a PC can be easily accomplished overnight on Darwin.

As the results of each group's simulations become available over the coming months, the data will be assembled and compared. Friend fully expects that this process will reveal differences: "each equivalent model has its own strengths and weaknesses. That's why the comparison process is so valuable – no single model is sufficient but together we can reduce the uncertainty."

Why is this so important? "To make policy you need to understand the impact of decisions," said Friend. "There hasn't been a coordinated impacts project for IPCC across sectors before, and now this is covering four key sectors across four climate change scenarios from multiple climate models. The idea is to understand at what point the increase in global temperature starts to have serious effects across all the sectors, so that policy makers can weigh up the probable impacts of allowing emissions to go above a certain level, and what mitigation strategies are necessary to avoid significant risk of dangerous climate change."

Dr Andrew Friend

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The research leading to these results has received funding from the European Community's Seventh Framework Programme (FP7 2007-2013) under grant agreement No. 238366.

A square in Rome's Jewish ghetto area, now renamed as a memorial to the deportation of Rome's Jews in 1943

As the birthplace of Fascism – and both ally and victim of Nazi Germany – Italy presents a particularly complex case study of how countries came to terms with the catastrophic events of the Holocaust after the war. Robert Gordon's new book charts the cultural fault lines that emerged as it slowly learned to acknowledge its part in the tragedy.

Memory remains

As the generation that witnessed the twin horrors of the Holocaust and World War II slips away, some have begun to fear that the devastating lessons of our recent history may grow faint with its passing. In the case of the Holocaust in particular, however, the level of remembrance seems remarkably high, as a profusion of memorials, museums, annual commemoration events and the mandatory study of the 'Shoah' on national curricula around the world attest.

It is difficult to believe that this was not always the case. At the end of World War II, what we now call the Holocaust was far from a matter of general discussion. Attention was focused on Allied victory and the building of a post-war world. What had happened in the camps was subsumed into that general narrative. The Italian Auschwitz survivor Primo Levi, later wrote: "At that time, people had other things to get on with: building houses, looking for jobs… People didn't want to hear [about the camps], they wanted other things."

Levi is a recurring figure in Robert Gordon's new book, *The Holocaust in Italian Culture, 1944–2010*, which explores how Italians have handled the memory of the Holocaust, but also the war, which intersects with it in unpredictable ways. Both are intertwined aspects of a global human tragedy, but in Italy this takes on particularly complex and troubling dimensions, because it was a former Fascist state and Nazi collaborator.

Researchers like Gordon have come to understand that the Holocaust was not the subject of sudden public concern at the war's end. Instead, most countries handled the cataclysm with an initial stance that almost resembles disregard. This was followed by a period of rediscovery in the 1950s and 1960s, and then growing awareness that peaked in the 1990s. Now, the Shoah is a general aspect of world history, perhaps the defining event of the 20th century, to some extent decoupled from the local contexts in which it was acted out.

Each country, however, also has its own story to tell and its own paths to memory. Surprisingly, how post-war Italy confronted, or at times failed to confront, its participation in the genocide has never been addressed by a major study. Gordon, a specialist in Italian culture, argues that by mapping cultural output about the Holocaust we can see how the nation's response to the catastrophe shifted over time. Through it, we see not just Italy's take on its Fascist past, but its engagement with the anti-Fascist Resistance,


PROFESSOR ROBERT GORDON

Cold War politics, the Church, Europe, immigration and multiculturalism.

"Encounters with the Holocaust can change the way we perceive ourselves," Gordon said. "In the 1960s, an Italian schoolchild might have read Anne Frank or Primo Levi. From the 1990s, class trips to concentration camps became common. Many children never forget this first contact, and even if they don't study it further, it comes to define their understanding of history, of their country and their identity."

Italy has made a significant cultural contribution to making the Holocaust a ubiquitous presence in our culture. Best known are the works of Levi, and the Oscar-winning 1997 film by Roberto Benigni, *Life is Beautiful*. Beyond these, however, lies a rich seam of less familiar first-hand accounts, works of fiction, poetry and drama, films and documentaries, television programmes, art, music, and architecture, museums, galleries and cultural events.

However, as in other nations, social and cultural recognition of what had happened started slowly in Italy. At the end of World War II, floods of people returned and the Jews were treated as part of a more general category of 'The Fallen' or the survivors, rather than as a special case.

The dominant local narrative stressed that the deportation of Jews had happened under the Germans, after the Italian government capitulated in 1943, and was a policy resisted by Italians themselves. "In 1945, the country wanted to be seen as a victim," Gordon said. "It wanted to get into the UN. The myth was propagated that the average Italian on the street had not wanted Fascism, had deep down been a decent person and was not really racist." Jews themselves, returning from the camps, saw little social value in exposing the crimes of their neighbours. They, too, wanted to rebuild.

The step-change came at the end of the 1950s, with the emergence of new first-hand accounts, such as those of Edith Bruck and Emilio Jani, historical reassessments by the likes of Renzo de Felice, and films such as Carlo Lizzani's *The Gold of Rome* (1961). Amid global reawakening about the Holocaust, triggered by the trial and execution of Adolf Eichmann, a new sense of responsibility to consider what had happened, and – eventually, Italy's part in the process – began to gain momentum.

As the space between the terrible events of the Holocaust and the present expanded, more people felt able to cope with personal accounts from the camps. Levi's *If This is a Man* had sold few copies when first published in 1947, but in 1958 a new edition boosted his reputation, which was then cemented by *The Truce* (1963). Such personal accounts, however, proved that the Holocaust could not be seen purely as a Nazi crime. The notion of Italian involvement was slowly gaining acceptance.

In the 1980s, a new generation of historians who believed that Italy was not telling enough of the truth about its wartime experience changed the picture again. Researchers began to reveal a network of Fascist concentration camps that had existed in southern Italy but had been largely forgotten. What followed was an outpouring of engagement with the Holocaust, boosted further by the fall of the Soviet Union, which enabled visits to sites such as Auschwitz.

Filmmakers, artists, architects and intellectuals had contributed to each of these waves of attention. They included authors such as Giorgio Bassani and Natalia Ginzburg, and directors such as Vittorio De Sica, Lina Wertmuller and Francesco Rosi. Many were determined to show specifically Italian aspects of the Holocaust, often in advance of wider acceptance of Italian involvement. In 1997, Benigni released *Life is Beautiful* and Rosi a film version of *The Truce*. "The conjunction of these films, both in their way focused on the specifics of an Italian inflexion to the history and experience of the Holocaust, is of cardinal importance in reading the cultural sensitivities of the moment," Gordon writes.

The crescendo built towards the first official Holocaust Memorial Day in Italy, its 'Day of Memory' in 2001, which Gordon calls "the high-water mark of the entry of the

***The Holocaust in Italian Culture, 1944–2010*, by Professor Robert Gordon, is published by Stanford University Press**

Holocaust into national public life in Italy." The event certainly showed how far the country had come in its acknowledgement of the Shoah, explicitly recognising the persecution of its own Jewish citizens and their deportation, as well as participating in an international commemoration.

Yet ambiguities still remained. The label 'Day of Memory' was deliberately neutral, and the date chosen, January 27th, was deliberately that of the anniversary of the liberation of Auschwitz – a date of international importance, certainly, but not specific to Italy.

In the 21st century, for the generation after *Life is Beautiful* and *Schindler's List*, the Holocaust is part of a shared, global history. At the same time, its local history still presents problems. Italy's part in perpetrating the tragedy is now a matter of widespread recognition and cultural reflection. But even now, the same nation occasionally struggles to place this awkward and terrible chapter within its shared national story.

"Encounters with the Holocaust can change the way we perceive ourselves."

Professor Robert Gordon

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Expanding the heart and lungs of medicine

Fundraising is under way for a joint Cambridge University and Papworth Hospital Heart and Lung Research Institute – to sit alongside the anticipated new Papworth Hospital on the Cambridge Biomedical Campus – enabling a major expansion of cardiorespiratory research in Cambridge.

Diseases of the heart and lung are some of the biggest killers worldwide. According to the latest figures from the World Health Organization, cardiovascular disease causes an estimated 17 million deaths per year, with respiratory disease ranking just behind with 4.2 million deaths. Despite a growing awareness of risk factors, such as smoking and poor diet, the prevalence of such diseases is increasing.

Cardiorespiratory research has seen significant growth in Cambridge over the past 15 years. The University now has five British Heart Foundation (BHF) professorships and three Chairs in respiratory medicine. Fundraising is under way to expand yet further, with the creation of a new Heart and Lung Research Institute (HLRI) by the University and Papworth Hospital, to sit alongside the new Papworth Hospital which is anticipated to relocate to the Cambridge Biomedical Campus.

"The growth trajectory in cardiorespiratory research here has been pretty phenomenal," explained Professor Martin Bennett, who holds the BHF Chair of Cardiovascular Sciences. "The ambition for the HLRI is to put two excellent partners together synergistically, achieve a critical mass of clinical and basic scientists who have a single focus on cardiorespiratory disease, and create something truly world leading."

"The HLRI will provide a virtuous cycle of discovery," added Professor of Respiratory Medicine, Edwin Chilvers. "By bringing together researchers of different disciplines – basic, clinical, population science – and adding a specialist R&D unit, you can cover every step in the chain from fundamental research through to drugs and devices being used in patients."

The Institute will allow for significant expansion of basic and clinical research capacity, with 40% new recruitment over and above existing staff levels, as well as enable the co-location of research groups that are currently dispersed across Cambridge.

Crucially, it will take research collaboration between the University and Papworth Hospital to a new level, as Chilvers explained: "There is already strong connectivity. Each institution has its own strengths: the University has huge basic science and translational research capacity, and Papworth is an international centre of excellence for the treatment of patients, some of whom have the rarest and most difficult to diagnose and treat forms of disease. The two have joint research and treatment programmes, and the new Institute will allow the scientists and clinicians to work geographically together for the very first time."

The research portfolio of the HLRI will be drawn both from the University, where the cardiorespiratory research portfolio amounted to £164 million last year in research grants from sources that include the BHF, Medical Research Council and Wellcome Trust, and Papworth Hospital, where nearly 140 active research projects are pioneering new treatments and surgical approaches.

However, the HLRI offers the opportunity for a major new strategic realignment of cardiorespiratory science. Chilvers and Bennett, together with Dr Ian Smith, Consultant Physician at Papworth Hospital, are responsible for developing the Institute's scientific vision, which has been organised under six themes: arterial disease, heart and lung failure, population studies, infection and immunity, lung cancer, and evaluation and implementation.

A growing area of research within the theme of heart and lung failure is the potential for stem cells to be used to repair damaged tissues, an area that is being led in Cambridge by Professor Karl Ludwig Laugwitz, who was recently awarded a BHF Professorship of Regenerative Medicine. The hope is that patient-specific stem cells derived from blood might be used to develop personalised treatments and generate options aside from transplantation for the repair of damaged organs.

Biomedical devices are central to the practice of cardiorespiratory medicine. Devices are used to open blood vessels and airways, replace heart valves, pace the heart and diaphragm, and assist the heart to pump blood and the lungs to ventilate effectively. "Papworth clinicians have led on the development of ground-breaking technologies, and there will be huge new opportunities when the HLRI is established at the heart of the Biomedical Campus," explained Smith, who will lead the evaluation and implementation theme, which will build on existing collaborations with University researchers and industry.

As well as focusing on achieving a better understanding of the basis of

Image (subject to final design selection) of the Heart and Lung Research Institute (left) and the new Papworth Hospital (right), which are to be located on the Cambridge Biomedical Campus

cardiorespiratory disease and its treatment, research at the Institute will be increasingly directed towards prevention and the interplay between genetics and lifestyle. A proposed Biomarkers Laboratory for population studies will translate the findings of several unique population studies on the causes of cardiovascular disease into strategies for predicting, preventing and treating diseases. Such studies include EPIC-Heart, an analysis of genes and lifestyle in 520,000 people across Europe that is being led at the Department of Public Health and Primary Care by Professor John Danesh, who will lead the population studies theme of the HLRI.

Clinical trials are also a critical part of the research process, and the Institute will incorporate a new and dedicated Clinical Research Facility. Already, for conditions such as pulmonary hypertension, Papworth Hospital is the largest referral centre in the UK, and new treatment strategies are benefiting from close ties with the Department of Medicine under the leadership of Professor Nick Morrell (see panel).

Not least, the HLRI will enable enhancement of education and training, as Bennett explained: "We want to be a major centre for training the next generation of clinical scientists in this area, as well as provide unrivalled opportunities to attract new investigators to the UK. The setup will allow unrivalled access to patients, and optimal support and facilities for translational and clinical studies. Our vision, once funding is in place, is to create a world-class research environment leading to improved patient care."

Breathtaking research

A translational research programme that links basic science in the University's Department of Medicine through to patient care at Papworth Hospital is pioneering new treatments for a fatal lung disease.

Professor Nick Morrell has his feet firmly in two camps. His team in the Department of Medicine carries out fundamental research on the molecular basis of pulmonary arterial hypertension (PAH), a rare lung disease that is characterised by narrowing of the lung arteries. Without a lung transplant, PAH can lead to heart failure just three years after the first symptoms of breathlessness appear. Meanwhile, as Research Director of Papworth's National Pulmonary Hypertension Service, he oversees the trialling of new treatments in patients who have severe PAH.

Recently, a Phase III trial demonstrated the success of a new treatment strategy, using the drug imatinib, based on targets identified by Morrell and colleagues. As Morrell explained, it represents a paradigm shift in treating PAH: "Unlike current treatments, the drug is inhibiting a growth factor pathway rather than dilating blood vessels. It's a completely different approach to treating the disease and possibly many others in the pulmonary hypertension family."

Morrell's team is also involved in a new drive to understand the genetic architecture of PAH. A large-scale genetic sequencing programme is now under way at the BioResource facility at the National Institute for Health Research Cambridge Biomedical Research Centre. By providing the first comprehensive genetic analysis of the PAH defect, the programme will help to identify new targets for drug discovery.

Both studies have benefited immeasurably from the strong linkage between the University's basic science laboratories and Papworth's National Pulmonary Hypertension Service. "We do translational research in a very joined-up way," explained Morrell, who holds the BHF Chair in Cardiopulmonary Medicine in Cambridge. "But there's a lot of goodwill that goes into making that happen. Proximity means so much, and being able to talk to people immediately about ideas and problems to overcome is more of a challenge if you are located in different places. To bring the basic research geographically closer to the clinical studies will achieve even more."

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"We have a unique opportunity to create a world-class environment to drive forward progress in translating cardiovascular and respiratory medicine research into improved patient care. A new Institute will enable us to draw together our existing strengths, develop collaborations and attract new expertise to ensure that we continue as a world-leading centre of innovation and care."

Professor Sir Leszek Borysiewicz
Vice-Chancellor,
University of Cambridge

Dr Ian Smith (left) and Professor Edwin Chilvers

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Body, soul and gold: quests for perfection in English alchemy

From the elixirs of legend to transmutation of base metals into gold, medieval medical practice and social mobility were steeped in alchemy.

We are often told that 'balance' is the key to life – work/family balance, a balanced diet, and so on. But in early modern England, the quest for the perfect balance was thought to lead to prolonged life, more gold than could be dreamed of, and even the possibility of surviving the apocalypse.

Alchemy was the science that made these goals seem possible. We think of alchemists as fixated on precious metals, but alchemy overlapped with a field with which we are all familiar – medicine, and the fight to stay alive.

For Dr Jennifer Rampling, from the Department of History and Philosophy of Science, the origins of English alchemy are bound up with beliefs about medicine and disease. Rampling's research, funded by the Wellcome Trust, takes a long-term view, spanning centuries – from 1300 to 1700 – and tracing the thread of English alchemy through hundreds of texts and manuscripts, taking in medicine, religion and culture.

At the start of this period, medicine was still guided by Ancient Greek and Roman notions about the need to balance the body's four humours – black bile, yellow bile, blood and phlegm. If a person was sick, an 'imbalance' of the humours was assumed, and it was the physician's job to rectify the situation by restoring equality.

"According to conventional academic medicine, illness wasn't something that invaded your body from outside. Everyone had their own individual 'complexion' of humours, and to rebalance this required a more-tailored, systemic healing method," explained Rampling.

"A common approach was to try and forcibly 'purge' excess humours, often considered the cause of illness, in order to rebalance. Bleeding and vomiting were routine forms of treatment."

But some diseases did not fit this ancient framework, and when the Black Death ravaged 14th-century Europe, killing tens of thousands regardless of individual complexions, physicians needed a new kind of medicine. Alchemy offered hope for a last-ditch cure.

A new alchemical medicine came into vogue – known as 'quintessence' – which went beyond conventional remedies, aspiring instead to the celestial. Made by repeatedly distilling alcohol, quintessence was used to extract essences from plants and metals, particularly gold.

In the medieval world view, the Earth was composed of the four Aristotelian elements: earth, air, fire and water. However, the heavens were made of a perfect, fifth element, immune to change and corruption. For alchemists, their distilled quintessences echoed this heavenly element, offering a potential cure by ejecting imperfection from the body.

"Plague was supposed to kill by poisoning the heart. But these elixirs were so perfect that they couldn't coexist with poison. The corruption would be literally forced out of the body – restoring the balance of health."

Chemical medicine began to catch on. Today, we aim for medication without violent side-effects. But in early modern England, the fact that powerful bodily reactions could be produced by ingesting tiny amounts of a chemical substance was seen as hugely impressive.

"Patients often welcomed strong, physical reactions to remedies – such as antimony compounds, which make you projectile vomit – because they saw them as indicators of effectiveness; perhaps that some blockage was being cleared," said Rampling. "If you think of your body as a sack of fluid humours, you will probably want to see, and feel, movement."

But if such concoctions could transform the flesh, why not metals as well? Rampling talks of 'slippage' between medical and metallurgical alchemy, and the most sought-after elixirs – such as the 'vegetable stone', a focus of her research – were believed to both heal sickness and transmute metals, purging impurity to leave only perfection.

Rampling has been in the lab with Dr Peter Wothers, from the Department of Chemistry, attempting to decipher an encrypted recipe for the vegetable stone by 15th-century alchemist George Ripley, perhaps the most influential of all English alchemists.

"If you distil vinegar several times, you can use it to dissolve lead. That results in a gum that Ripley called the 'Green Lion', but that modern chemists would think of as lead acetate," explained Rampling. "Distil this, and a white smoke is produced which – if you collect and condense it – forms a clear fluid. Ripley thought this 'menstruum' was the basis

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Image from a George Ripley Scroll, MS.276

"A lot of the alchemists' rhetoric is about protecting the secret: knowledge that is too dangerous to fall into the hands of the ignorant or rapacious."

for the vegetable stone." But the recipe fades into opacity as the alchemist's language becomes increasingly enigmatic.

Alchemical practices and ingredients were often concealed using symbolic, riddling language, enticing with their hint of otherworldly secrets, but ultimately difficult to decipher. This language is magnificently displayed in the 'Ripley Scrolls' – emblematic scrolls full of dazzling imagery, depicting dragons, angels, turrets in the clouds and giant droplets of blood.

These scrolls baffle at every level. The design is probably not by Ripley at all – it was attributed to him after his death, when his fame had spread. Their meaning was also subject to distortion over time. For 300 years, copyists emphasised different aspects of the scrolls' imagery, struggling to make sense of their source.

Such eye-catching manuscripts offered alchemical practitioners one way of marketing their expertise. Knowledge is power, and the natural and medical knowledge promised by alchemical treatises could be used as a bartering chip for social mobility by those who claimed to be its gatekeepers.

"A lot of the alchemists' rhetoric is about protecting the secret: knowledge that is too dangerous to fall into the hands of the ignorant or rapacious," said Rampling. "In reality, they had to be discreet with this knowledge, since it was their livelihood."

"Practitioners could use this knowledge to win the patronage of princes and nobles, by dangling the possibility of long life, riches and secret wisdom. The imagery of the Ripley Scrolls refers to medicine as well as transmutation – all in a very glamorous package."

Besides prolonged life and wealth, alchemy also offered insight into the secrets of nature, and even divine power. In Aristotelian cosmology, the Earth itself was flawed as it lacked the unchanging perfection of the heavens. As Rampling points out, this model "mapped very nicely" onto a Christian theology that viewed the natural world as damaged by original sin: "If nature was poisoned by the Fall, then alchemy promised to redeem it. It's no coincidence that the Ripley Scroll (pictured) shows the Garden of Eden."

By generating perfection on Earth, alchemists could claim they were doing God's work. The quest for the perfect elixir, able to purge both man and metal, had a powerful apocalyptic resonance.

For hundreds of years, Christian prophets claimed that the end of the world was close. On Judgement Day, God was expected to 'purify' the Earth with divine fire – only the perfect could survive. Some alchemists argued that the possessor of the elixir would play an important role. This idea resurfaced in Elizabethan England, and was presented to Queen Elizabeth I a number of times.

But corruption and redemption were also allegories for material processes. Tellingly, the Scroll's Adam and Eve are not eating the biblical apple, but bunches of grapes. Rampling has an answer: "Wine made from grapes produces both vinegar and the quintessence – key ingredients of the vegetable stone."

For all its striving for perfection, alchemy remained grounded in the physical, requiring its practitioners to get their hands dirty. For Rampling, there is a romance in the alchemists' relationship with the world, one we have perhaps lost.

"These people knew materials in an intimate way – they would taste them, smell them, listen to them. There are lots of descriptions in manuscripts of substances making cracking sounds, or producing a heavenly odour or bitter taste. Alchemists were early explorers of the material world. With only their senses and imagination to guide them, they had to be attuned to the slightest variation."

JACQUELINE GARGET

Dr Jennifer Rampling

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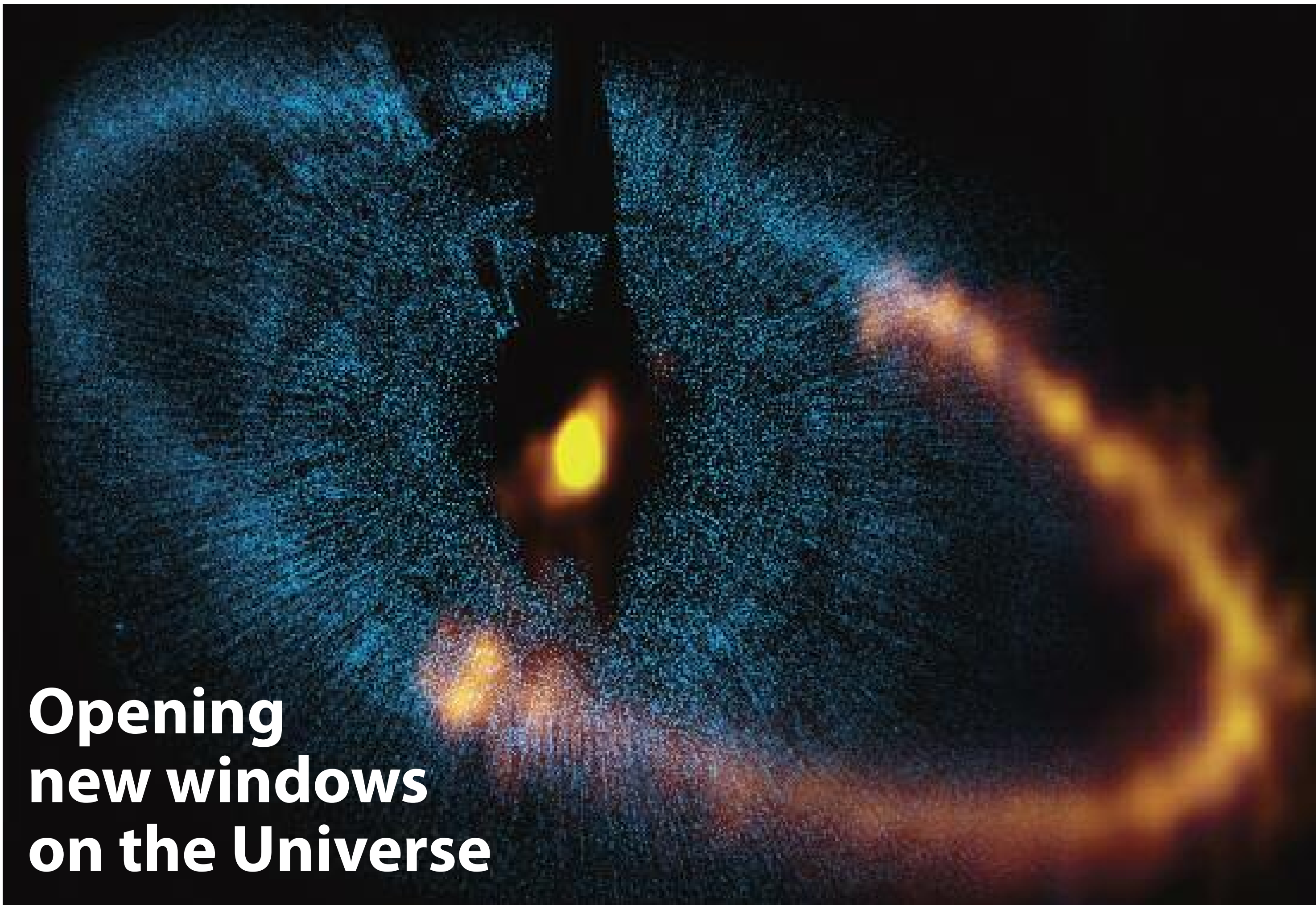

Opening new windows on the Universe

A new picture of the dust ring around the bright star Fomalhaut from ALMA; the underlying blue picture shows an earlier picture obtained by the NASA/ESA Hubble Space Telescope

Advances in telescope technology being developed at Cambridge will drive a revolutionary period of discovery in astronomy.

How do planetary systems form? What do the surfaces of stars look like? Does life exist elsewhere in the Universe? Astronomers have developed many theoretical models, but until now the ability to validate these with observations has been severely constrained by the telescope capabilities available.

Taking the lead in three major new international projects, Cambridge astronomers are tackling the enormous technical challenges involved in developing bigger and better telescopes to open new windows onto the Universe. Building on Cambridge's strong legacy of achievement in astronomical instrumentation, the new telescopes all utilise one important underlying technique –interferometry by aperture synthesis – to probe the Universe at a level of detail far beyond the capabilities of any telescope currently in existence. Each telescope will detect light at a different wavelength and help to build a fuller picture of exactly what is out there.

Filling in the detail

"When we look at regions of star formation with the best existing high-frequency radio telescope, we see blobs. We can learn a lot by looking at the radio waves that come out of these, but inside there will be all sorts of complicated structures that the telescope can't resolve," said Dr John Richer, astrophysicist at the Cavendish Laboratory and the Kavli Institute for Cosmology.

Richer is UK Project Scientist for the Atacama Large Millimetre Array (ALMA), a partnership project involving Europe, North America, East Asia and the Republic of Chile. Currently under construction in Chile, this revolutionary sub-millimetre radio telescope will consist of 66 high-precision antennas working in perfect synchrony when fully operational in 2013.

Interferometry will be used to combine the information they collect, 'synthesising' an aperture with an effective diameter of 16 km to create an ultra-high-resolution telescope. Professor Richard Hills, who is currently on secondment in Chile, designed the set of radio receivers that calibrate the telescope and are central to ALMA achieving its scientific goals, and Richer's team is developing the software to correct the images from ALMA.

"ALMA is an incredible piece of engineering that will enable us to zoom in to take pictures with a thousand times better resolution than we can now, so we'll actually see all the detailed structure instead of blobs," said Richer. "We're hoping to unlock the secret of how planetary systems form, and to look back in time at the very early Universe."

"We'll be able to look for evidence of unintentional radio emissions, the equivalent of airport radar, from our nearby stars and planetary systems that may indicate intelligent life."

With 33 of the antennas currently operational, the telescope is already returning stunning images. "The whole astronomical community wants to use ALMA because it's unique, and a huge breakthrough in capabilities," said Richer. "There's an unprecedented level of oversubscription, because nearly everything in the Universe has some emission at these radio wavelengths that is interesting and not well understood."

Building a fuller picture

Dr David Buscher and Professor Chris Haniff, astrophysicists at the Cavendish Laboratory, are system architects for the Magdalena Ridge Observatory Interferometer (MROI), a collaborative project with New Mexico Tech, USA, that also uses interferometry, but this time at visible wavelengths.

"Optical interferometry provides information not available from conventional optical telescopes or from radio interferometers," said Buscher. "Both radio and optical interferometers can see fine detail: putting together this detail allows us to answer new questions."

The pair started with a set of high-level scientific questions, drawn up by a consortium of UK astrophysicists, and used these to specify a new high-precision optical array. "The great thing about this project is that we've been able to design and build, from scratch, an instrument to answer fundamental scientific questions that cannot be answered in any other way," said Buscher. Haniff added: "We are involved in all the major design questions, from what size telescopes are the best, to how many, to which configuration would produce the best images, and we're developing the software that will make images from the data."

When constructed on its mountain-top site in New Mexico, the MROI will be the lead instrument in its field, consisting of 10 telescopes that will produce images with 100 times the resolution of those from the Hubble Space Telescope. By looking at external galaxies, it is expected to revolutionise understanding of astrophysical phenomena ranging from active galactic nuclei to black holes. Closer to Earth, it will help answer questions about the formation of stars and planets.

"There are models for what's going on," said Haniff, "but these could be completely wrong – at the moment the detail is far too fine to see. By using interferometry to simulate the resolving power of a single optical telescope of up to 340 m in diameter, the MROI will enable us to see structures that are so small they couldn't otherwise be detected at visible wavelengths." The advanced technology of the MROI could also have important commercial applications, such as in taking images of broken telecommunications satellites in geostationary orbit to help diagnose what has gone wrong.

Signs of life?

The third telescope in the trio, the Square Kilometer Array (SKA), will be the largest and most sensitive radio telescope ever, and its design involves astronomers, engineers and industry partners from 20 countries. Professor Paul Alexander, Head of Astrophysics at the Cavendish Laboratory, is playing a leading role in its development. Involving a 'sea' of antennas – over half a million in the first phase – acting as one enormous interferometer covering 1 km^2, the concept calls for a very simple design with low unit cost. "At the moment we're working very closely with our industrial partner, Cambridge Consultants, on the detailed design," he said. "It's also going to be a major computing challenge – the data transport from the dishes will produce 10 times the current global internet traffic."

With one of its design goals being "to maximise the ability to explore the unknown", SKA will enable astronomers to see incredibly faint signals. "With SKA we will be able to look back to the time when the first objects formed in the Universe, and try to understand how we got from there to what we have now," explained Alexander. "A second experiment will use pulsars, originally discovered by Antony Hewish and Jocelyn Bell-Burnell in Cambridge, as extremely accurate natural clocks. Finding a pulsar in orbit around a black hole will enable us to properly test Einstein's gravitational theory."

This extremely powerful telescope also provides an exciting new approach to the search for extra-terrestrial intelligence (SETI). "The trouble with most SETI searches is that they rely on someone communicating with you just at the time when you're listening," said Alexander. "SKA is so much more sensitive than anything we've had before. We'll be able to look for evidence of unintentional radio emissions, the equivalent of airport radar, from our nearby stars and planetary systems that may indicate intelligent life."

Although work on SKA has already begun, construction will not start until 2016 and the telescope will not be fully operational until 2024. Development work for all three telescopes extends back decades, as Alexander explained: "We're building on our legacy". The idea for interferometry was originally conceived in the 1880s, but it wasn't until the 1950s that it was developed and used at radio wavelengths – a technique for which Cambridge astronomers Martin Ryle and Antony Hewish won a Nobel Prize in 1974. It was also in Cambridge in the 1980s that reliable interferometric imaging was first shown to be feasible at optical wavelengths, and this paved the way for building the MROI.

A challenge of many disciplines

"To build these big telescopes you need teams of people with expertise across astronomy, technology and computing," explained Alexander. "You've got to pull everyone together to do good, competitive science". Recognising this, the University plans to build a new Centre for Experimental Astrophysics to enable greater integration of its strengths. Construction of the Centre will begin this October on a site adjacent to the University's Kavli Institute, thanks to generous philanthropic support from Cavendish Alumnus Mr Humphrey Battcock and The Wolfson Foundation. "The new building will enable us to create the teams needed to take on these big scientific challenges, which will lead to major advances in our knowledge and understanding of the Universe," said Alexander.

(Left to right) Dr David Buscher, Dr John Richer, Professor Chris Haniff and Professor Paul Alexander

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How the brain is made

By combining advanced imaging with powerful genetic labelling techniques, Professor Bill Harris has imaged the entire process of retinal development in four dimensions, providing new insights into the enormous complexity of the nervous system.

With an incredible diversity of cell types, the central nervous system (CNS), comprising the brain, spinal cord and retina, can be considered to be the most complex organ in the body. Professor Bill Harris, an experimental biologist and Head of the Department of Physiology, Development and Neuroscience, is fascinated by how this complex and sophisticated system is built out of a collection of undifferentiated cells. By putting an advanced technology to novel use, he has been able to observe for the first time the entire process of retinal development at the cellular level in zebrafish embryos. This has achieved a long-sought goal in developmental neurobiology: a complete analysis of the building of a vertebrate CNS structure *in vivo.*

Terra incognito

"What surprises me most is the inscrutable logic of it all," said Harris. "Every experiment designed to differentiate between different hypotheses leads down one or other branch of an untravelled winding way, through a complex and cleverly evolved network that eventually leads to the functioning CNS."

"We use the retina as a model for the rest of the brain, and zebrafish are a useful research model species because their transparent embryos are easy to see into, and develop rapidly," he added. The zebrafish process of retinal development is complete by about three and a half days after fertilisation; in humans, it takes up to a year. Focusing on the developing visual system in this lower vertebrate, Harris has broken the process down into discrete events to unravel some of the mysteries that lead to the formation of a perfectly built nervous system.

"At 24 hours after fertilisation, to an inexperienced eye, all the cells of the embryo look the same," explained Harris. "But already the decisions as to what they will become have been made. The little bulge that is destined to become the eye is now committed, but all the cells within that bulge still have the potential to give rise to various types of retinal neurons. We call those retinal progenitor cells (RPCs)".

Harris' research focuses on understanding how the cellular diversity in the retina arises: how the RPCs produce different cell types, and how, what and when decisions are made. He and his colleagues have found that each RPC seems to behave individually, producing clones of variable size and composition. One of the big puzzles is how, from beginnings that show such variability, a retina of just the right size and cellular composition forms. "The fully formed retina has a hundred different types of neurons. I want to know how it all comes about so perfectly," he said, "it's a terrific puzzle, and a fundamental issue in developmental neuroscience."

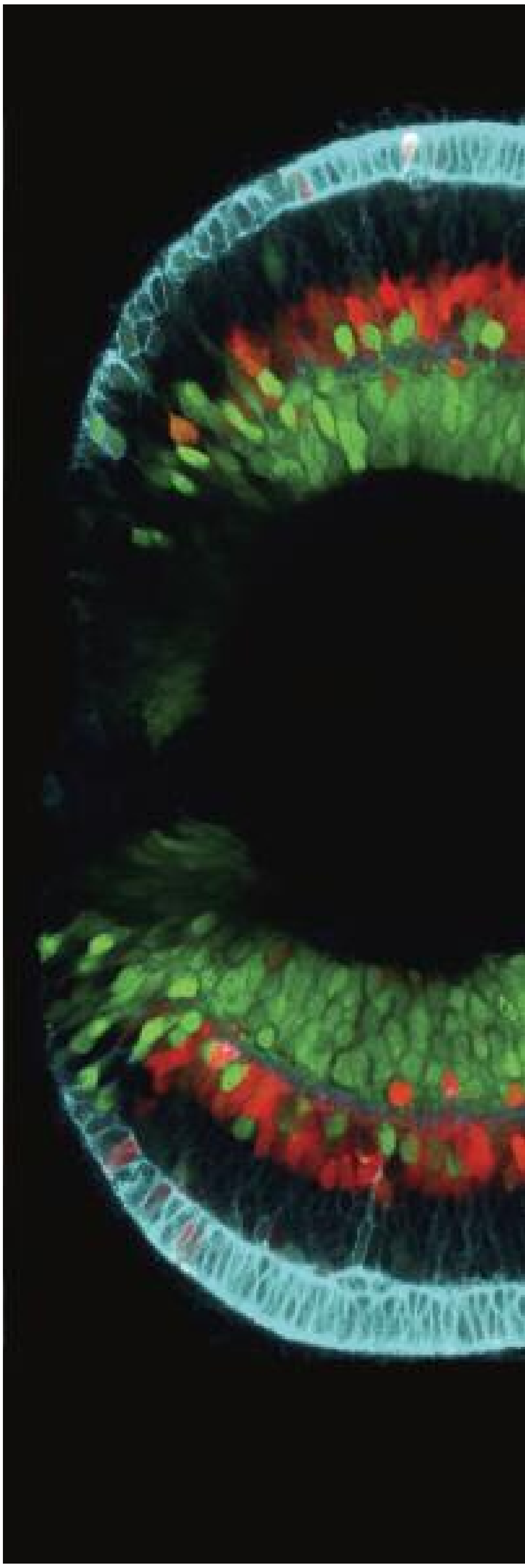
Pushing boundaries

Combining imaging with powerful genetic labelling techniques helps to elucidate the fine detail. "We discovered a zebrafish gene that was necessary for the formation of retinal ganglion cells, the first cells to exit the cell cycle and start to differentiate," said Harris. "We used the promoter of that gene to drive a fluorescent protein, then when the gene was turned on just before the final division of the RPC, it made the cell fluorescent," said Harris. These fluorescent cells can then be followed under the microscope throughout retinal development.

Harris uses a sophisticated confocal microscope to take a set of images of labelled cells in the developing zebrafish embryo in a single plane, and then stacks them to build up a 3D view of the cells. By repeating this at regular intervals, a 4D, or time-lapse image, is created over several days that shows the set of undifferentiated cells proliferating and differentiating into particular types of neurons. A pioneer of this approach, he has transformed the way scientists can look at the developing brain. An article due to be published in *Neuron* this year describes his ground-breaking work.

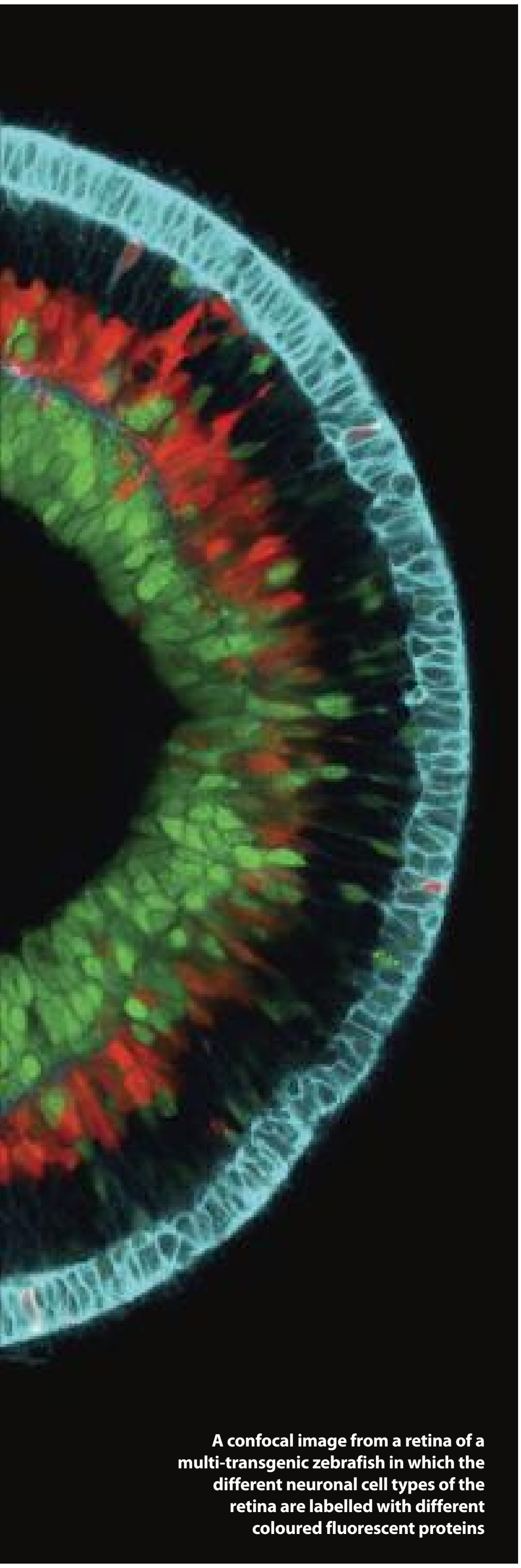
"Forty years ago you would look at the embryo and label some cells, then later look again to see what cells were now labelled or where they were. You'd get snapshots under the microscope and surmise what happened in between. Now we are actually seeing how the cells divide, which gives us a lot more information to help distinguish certain hypotheses from others," said Harris.

"We've made some spectacular movies where we can actually see the RPCs going



To view one of Bill Harris' movies of the developing retina, please visit www.cam.ac.uk/research

"What surprises me most is the inscrutable logic of it all."



A confocal image from a retina of a multi-transgenic zebrafish in which the different neuronal cell types of the retina are labelled with different coloured fluorescent proteins

DR XANA ALMEIDA, DR HENRIK BOIJE AND PROFESSOR BILL HARRIS

through cell division to produce two daughter cells *in vivo* in the retina. We also see transient processes that people didn't notice before," Harris added. "We see that all the RPCs remain attached to one side of the epithelium by a tiny little thread throughout cell division. Since the 1930s, we've known that the RPCs let go of one side but we'd never seen this thread before. Now we want to know what its purpose is – is it important for keeping a cell arranged in the right way? Does it serve a purpose later on in development?"

Using 4D analysis for hundreds of cells at different stages throughout retinal formation, Dr Jie He, a Postdoctoral Fellow in the Harris lab, found there was a stochastic, or chance, element involved in the types of daughter cells formed each time a cell divides. In collaboration with Ben Simons, Professor of Theoretical Physics at the Cavendish Laboratory, they developed a model to explain this variability in the proliferation of RPCs, and how, in spite of this variability, RPCs managed to produce a perfect retina every time.

Cambridge Advanced Imaging Centre

Harris is driving the development of a new purpose-built imaging centre – the Cambridge Advanced Imaging Centre (CAIC) – which opens in October 2012 and has been made possible through generous funding from The Wolfson Foundation, the Wellcome Trust and support from the University. By augmenting the best commercial and University-developed instruments, this facility will offer to the broader scientific community the latest developments in light and electron microscopy, adapted to specific scientific questions, with the aim of accelerating progress in research across a broad range of areas.

"CAIC will enable us to look inside a living tissue at any resolution from single molecules to thousands of cells, and see the machinery that's operating there in real time," said Harris. "It took us three years to track the hundreds of cells in our study. Once the new microscopes are built, they will perform at a much higher resolution, and much faster," said Harris. "Our hope is to be able to see all the RPCs dividing and giving rise to all the cells in the retina, and to do this over several embryos and see the variations so that we can properly describe the statistical properties. We also need a lot more data to understand the nature of the stochastic machine that generates the right proportions of different cell types, and CAIC will help us do that."

Human aspect

The process Harris has observed in the zebrafish also occurs in humans, and a challenge for the field will be to understand how the stochastic machine changes so that human-sized retinas come out of a collection of human RPCs. Beyond the field of neural developmental biology, Harris' findings may have far-reaching implications.

"The repair of neural tissue is a very challenging field. In order to make progress, it is often helpful to understand more about how the brain is originally made, then try to recreate that in an injured brain. Scientists at Cambridge's Brain Repair Centre are using ideas from neural development in this context," said Harris. "A better understanding of the control and regulation of cell proliferation is also highly relevant to research into neural-origin cancers. The more we understand retinal development, the more information we can feed into the development of novel therapies."

JACQUELINE GARGET

Professor Bill Harris

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Science illuminating art

Illuminated manuscripts are revealing their secret histories thanks to the application of techniques more commonly found in scientific laboratories.

Fairy-tale pinnacles stretch to the horizon in an azure sky, scarlet flags flutter, an angel plays a golden horn, and the Madonna, shrouded in folds of tumbling ivory, serenely cradles her newborn baby. This painting (pictured) is one of the many that illuminate *The Hours of Isabella Stuart*, a sumptuous prayer book illustrated by a group of French painters in the 15th century.

All that is known and speculated about the manuscript, which is part of the rich collection of illustrated manuscripts in Cambridge's Fitzwilliam Museum, has been pieced together from painstaking art historical analysis and circumstantial evidence. But much remains shrouded in mystery. Who designed the exceptionally rich and complex images? How were they to be used? Were they the creation of a workshop, with the Madonna painted by the workshop master? Or did several masters make guest appearances? Did the artists share materials and techniques? Where did the pigments come from?

Now, thanks to an innovative project at the University of Cambridge, some of the hidden histories of the *Book of Hours*, and many other illuminated manuscripts, will be uncovered. Led by Dr Stella Panayotova, Keeper of Manuscripts and Printed Books at the Fitzwilliam Museum, and Professor Stephen Elliott, from the Department of Chemistry, the MINIARE project is using scientific techniques to identify the composition of illuminations. The research will help conservators repair priceless works of art and provide new insights into the cultural, social and economic circumstances of their production. And, crucially for objects of such rarity and fragility, none of the techniques involves touching the manuscripts or removing samples.

Illuminated manuscripts often have long and complex construction histories: a manuscript copied in Italy in the 1300s, for instance, might receive its illumination in France decades later and be bound in Germany. "This is a reflection of the trade routes operating at the time and the international mobility of artists, scholars, patrons, manuscripts and ideas," said Panayotova, "but it's also a consequence of war and of political and religious upheaval."

Scientific analysis of the pigments can provide valuable contextual information, as research scientist Dr Paola Ricciardi is discovering. Using analytical techniques such as fibre optic reflectance spectroscopy and X-ray fluorescence, as well as visual imaging techniques such as microscopic observation and infrared reflectography, she is identifying the composition of pigments as well as revealling underdrawings and preparatory sketches.

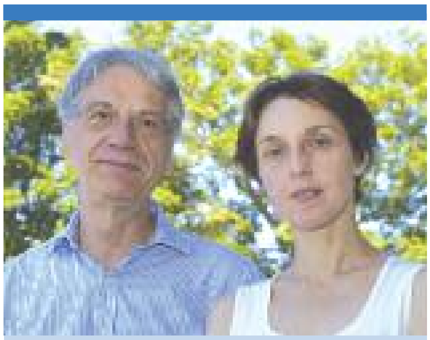
"The challenge for the chemists and the physicists in the team is to use well-known scientific techniques in a new situation, where very low concentrations of complex mixtures need to be identified as a function of depth," explained Elliott. "One of our interests is to push the technology to its limit by building new hardware that can analyse the fingerprint of paint at the sub-micron scale."

Member of the project team, Dr Spike Bucklow from the Hamilton Kerr Institute – a department of the Fitzwilliam Museum that specialises in the conservation and restoration of paintings – explained why the project will bridge the gap between science and art: "Artists had a fantastic knowledge of how to get the effect they wanted from the pigments they used. How much they knew about why the materials worked is of great interest. This research will help to unpick the art of manuscript illumination."

The goal is to expand the current project, which has been funded by the Newton Trust and a private sponsor, to encompass not only the 2,000 manuscripts held by the Fitzwilliam Museum, but also those held by the University Library and Cambridge Colleges, and the team is actively seeking new funding to do this.

"Art historical and linguistic research can take you a long way towards answering questions but scientific analysis can clinch arguments and dispel myths," said Panayotova. "There are very few institutions in the world that combine such rich collections with multidisciplinary expertise. This unique synergy will have a very significant impact, informing a larger study of the changing artistic, cultural, ideological, social, political and economic environments in which the manuscripts were created."

Painting from *The Hours of Isabella Stuart*, France (c.1431); MS 62, fol. 141v



Professor Stephen Elliott and Dr Stella Panayotova

For more information, please email info@miniare.org or visit www.miniare.org

MINIARE (Manuscript Illumination: Non-Invasive Analysis, Research and Expertise) is a collaboration between the Fitzwilliam Museum, the Hamilton Kerr Institute, the Departments of Chemistry, Physics, History of Art, History and Philosophy of Science, and the Victoria & Albert Museum.

To view a video about the MINIARE project, please visit www.cam.ac.uk/research

Research online

If you're interested in finding out more about research at the University of Cambridge, take a look at our dedicated website (www.cam.ac.uk/research). Here you'll find news, features, discussion, themed areas, videos and audio that cover research across the disciplines, all in a fully searchable and easy-to-use format. The latest themed area focuses on Risk and Uncertainty, launched to coincide with this issue of *Research Horizons*. And, if you'd like to keep up to date by email with what's new on the website, you can subscribe to our weekly e-bulletin at www.cam.ac.uk/research/bulletin

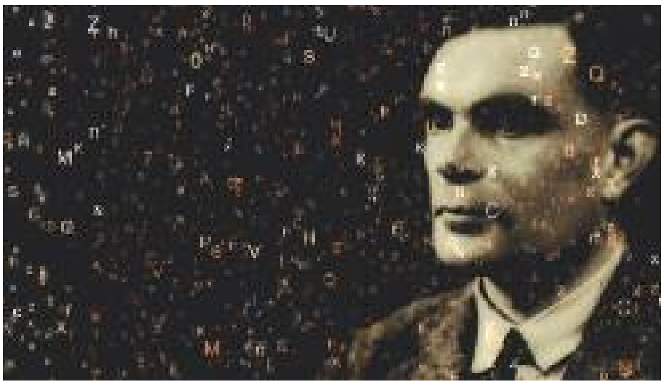
A selection of the latest video and audio:

Video: The Future of Energy

The most recent film in the flagship *Cambridge Ideas* series examines the world's skyrocketing consumption of energy, and asks what technology and behavioural change can do to help. Dr Richard McMahon, Professor Andy Woods and Dr Julian Allwood look at wind power, carbon capture and storage, and material efficiency as examples of how we can cut emissions. They suggest that we must act now in order to avoid the serious risks of man-made global warming, one of the greatest challenges of the 21st century.

Visit: www.cam.ac.uk/research/video-and-audio/the-future-of-energy

Video: Alan Turing – celebrating the life of a genius



We celebrate the centenary this year of the birth of Alan Turing with a short film on his life and work. Perhaps best known for his part in breaking the German Enigma code during World War II, Turing had, aged 22 years old at King's College, Cambridge, already conceived of the 'Turing Machine' – a universal machine that could imitate all possible calculating devices. This mathematical model went on to become one of the cornerstones of computer science and is arguably the most influential mathematical abstraction of the 20th century.

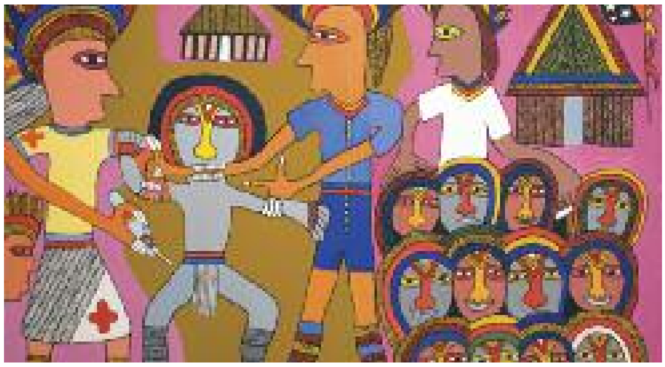
Visit: www.cam.ac.uk/research/news/alan-turing-celebrating-the-life-of-a-genius

Photo film: Welcome to Bastion – war zone ethnography with the combat surgeons

Dr Mark de Rond from the Cambridge Judge Business School was given unprecedented access to the military hospital at Camp Bastion in Afghanistan to study the teamwork of the combat surgeons. The unique photographs he took – now the subject of this photo film – reveal the realities of life and death in the operating theatre of modern war. For six weeks beginning in June 2011, de Rond embedded himself with the surgeons at the field hospital to study how these high-performing teams work together under extreme pressure, forced to make life and death decisions in the blink of an eye and deal with harrowing injuries.

Visit: www.cam.ac.uk/research/news/welcome-to-bastion-warzone-ethnography-with-the-combat-surgeons

Video: 'Everything, everywhere, ever' – a new door opens on the history of humanity



Take a short video tour through the newly reopened Museum of Archaeology and Anthropology after its £1.8 million redevelopment. Home to one of the finest and most important collections of its kind in the country, the Museum charts the history of humanity, from our earliest ancestors to today's indigenous people spread across the globe.

Visit: www.cam.ac.uk/research/news/everything-everywhere-ever-a-new-door-opens-on-the-history-of-humanity

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