Research Horizons

Pioneering research from the University of Cambridge

Issue 22

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Sustainability & the environment

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‘Big data’ and education

UNIVERSITY OF CAMBRIDGE
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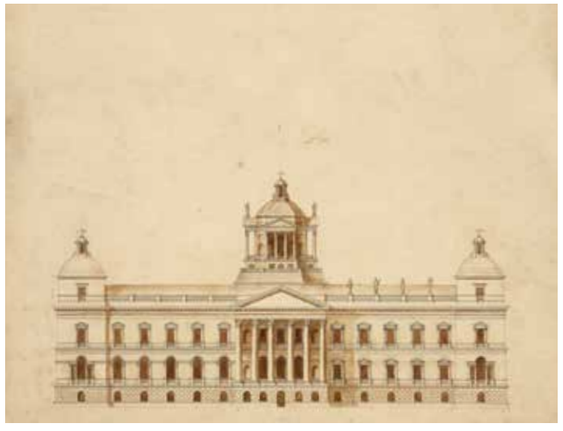

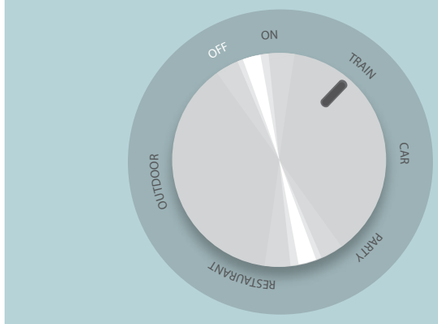

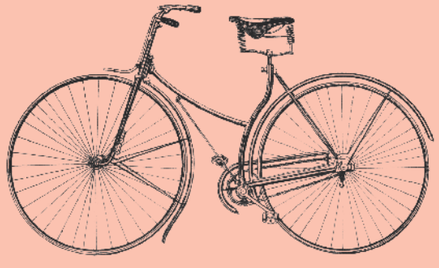

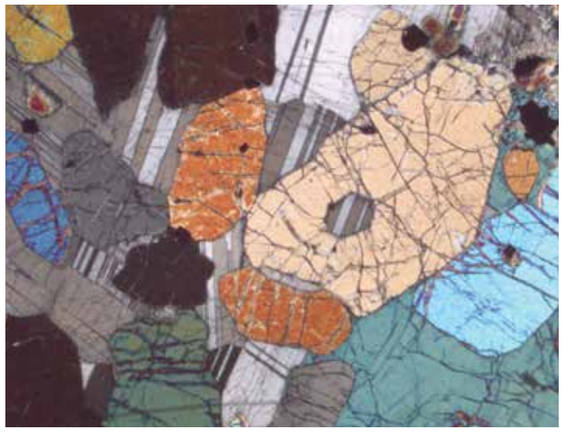

Welcome

Sustainability can be a slippery concept to grasp. Reducing carbon emissions, conserving biodiversity, using the planet’s limited resources more efficiently – all of these issues, and more, are important pieces of the puzzle. But understanding how the pieces fit together, and how they can be achieved without detrimental impacts on society, the environment and the economy, is complex. Unfortunately there is no silver bullet: the solutions will need to be ‘multi-pronged’ and multidisciplinary, requiring the connection of knowledge from many different sources.

Connectivity is the heart of an innovative new Forum within the University made up of 20 of the University’s leading experts in areas ranging from energy, biodiversity and food security to anthropology, architecture, history and economics, who this year have formed the Cambridge Forum for Sustainability and the Environment. A series of articles in this issue gives a snapshot of the breadth of research into different aspects of sustainability and the environment across the University: from the development of new sources of energy and the design of sustainable houses and factories of the future, to the human story of climate change as perceived by those living in the shadow of the Himalayas.

Societal and cultural change are a key part of sustaining the environment. Two other articles in this issue describe how researchers are also investigating how societies have perceived and adapted to change, but in response to two very different drivers: the economically driven shift from cow to camel farming in Kenya, and the impact of printing over a 400-year period in Russia from the mid-15th century.

Elsewhere, we examine the importance of ‘big data’ and the linking of datasets containing vast amounts of information on education in the UK, plus research on deafness, volcanic rocks, intonation, how viruses hide, and designs for a very different Houses of Parliament. We hope that you enjoy this issue of *Research Horizons*.

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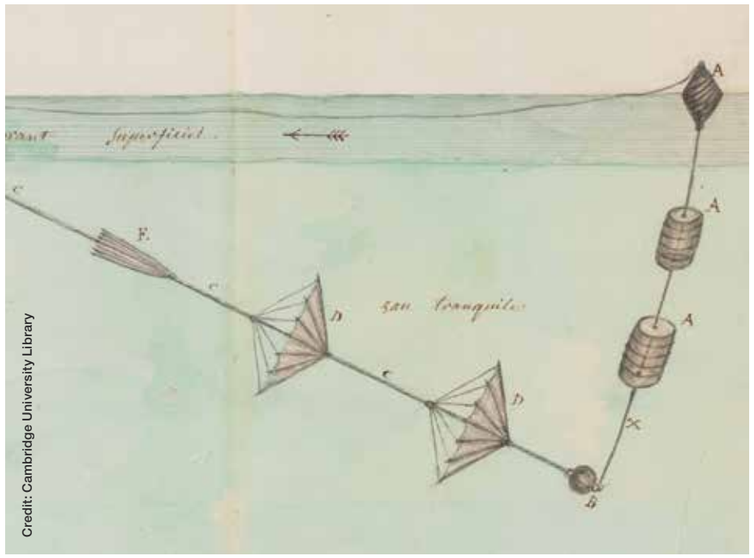
News



Credit: Cambridge University Library

Board of Longitude archive digitised

Image
Proposal for finding longitude by determining the ship's rate of sailing

The full story of attempts to solve the 'longitude problem' is now freely available via Cambridge University Library's Digital Library.

In July 1714, when the Board of Longitude was suggested, an act of parliament established a £20,000 prize, worth about £1.5 million today, for the discovery of longitude at sea – determining a ship's position east and west from a fixed meridian line. Now, the fascinating story of how the 'longitude problem' was solved, as told through the Board's detailed meeting minutes, held by Cambridge University Library and associated National Maritime Museum collections, is freely available to view in high resolution.

Treasures include accounts of bitter rivalries, wild proposals and first encounters between Europeans and Pacific peoples; the naming of Australia; and even a letter from Captain Bligh of HMS *Bounty*, who writes that his ship was "pirated from my command".

Comprising more than 65,000 images, it is the largest project undertaken to date by the University Library's Digital Library project, which was launched following a £1.5 million gift from the Polonsky Foundation. Digitisation of the archive was funded by JISC and is part of a wider research project by the Department of History and Philosophy of Science (HPS) and Greenwich's National Maritime Museum.

"The longitude story is a spectacular example of expert disagreement and public participation," said Professor Simon Schaffer, from HPS. "As well as attracting the greatest scientific minds of the day, the Board enticed people who belong to one of the most important traditions in British society: the extreme eccentric."

Dear digital diary…

A newly developed life-logging tool captures and stores memorable moments in people's lives.

'Storica', created by Dr Dirk Trossen, at Cambridge's Computer Laboratory, and Dana Pavel, at the University of Essex, tracks users' behaviour through their smartphones and computers, then combines the information to form an intricate, digital depiction of their day-to-day lives.

The researchers behind the software say that their creation will enable people to capture moments they might otherwise forget, and at the same time monitor the influences that are having the greatest impact on their lives. They are now planning to commercialise Storica with the help of the crowd-funding website Kickstarter.

'Life-logging' is an increasingly popular concept that capitalises on the fact that many smartphones have sensors which can record facets of people's behaviour. But, until now, most life-logging apps have monitored specific aspects of people's lives, such as their fitness, food intake, or mood. Storica will attempt to create a more complete picture, then play that back to users in fine detail via a mind-boggling array of visual depictions.

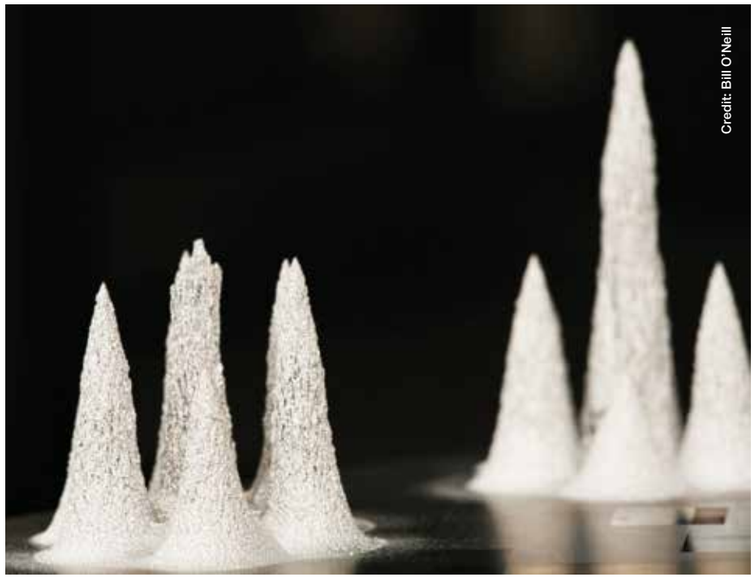
"At a more profound level, however, the software can also record information about what prompts certain behaviours, or when we are at our most stressed out, or relaxed," said Trossen. "Over time, it should enable users to improve their awareness of the factors which are shaping their lives, enabling them to analyse their lifestyles and hopefully improve them for the better."

News in brief

More information at www.cam.ac.uk/research

29.08.13
Astronomers show that giant black holes reject gas clouds – their 'food' – when the clouds are too hot to swallow.

24.07.13
The cost of Arctic methane release from shrinking sea ice could be the "size of the global economy", experts warn.



Credit: Bill O'Neill

Bit by Bit

Image
Supersonic laser deposition

Digital fabrication and 3D printing: a manufacturing revolution or an overhyped technology? New research will examine its true value.

With their promise of on-demand, mass personalisation and sustainable production, digital fabrication processes like 3D printing and supersonic laser deposition are moving from the domain of prototype manufacturing to product manufacturing – anything from spare parts for the washing machine to spare parts for the body.

But what is the reality and potential of digital fabrication for the UK economy? A new research project, 'Bit by Bit', aims to examine the technology's real impact.

"Digital fabrication has the potential to disrupt the organisation of manufacturing and the ways in which companies create and capture value, but there is a danger that it is becoming overhyped," said Dr Tim Minshall from the Department of Engineering's Institute for Manufacturing (IfM) and the project's Principal Investigator. "The aim is to help the academic, industrial and policy making communities target the most pressing questions and challenges."

With funding from the ESRC and EPSRC, Minshall will be working with a cross-disciplinary team from the IfM, the Department of Politics and International Studies, and the Centre for Science and Policy.

Over three years, the researchers will investigate how digital fabrication emerged, identify the trends, barriers and enablers, examine how companies are making money from the technology, and identify key policy support actions to underpin building value.

www.dfab.info

Funding for mental health

Research into the care of people with mental health conditions has been boosted by £10 million NIHR funding.

The NIHR Collaboration for Leadership in Applied Health Research and Care (CLAHRC) East of England is being set up to conduct pioneering research on the needs of patients and service users, focusing on dementia, patient safety, health economics, and how best to involve patients and the public in health care and research.

CLAHRC East of England is a collaborative effort between mental health service providers and researchers, and is hosted by Cambridgeshire and Peterborough NHS Foundation Trust with the involvement of the Universities of Cambridge and East Anglia.

Professor Peter Jones, Director of CLAHRC East of England and Head of Cambridge's Department of Psychiatry said: "I am delighted that NIHR has awarded this funding. The aim of the CLAHRC is to ensure the findings of academic studies can be used to make a real difference to front-line patient care as soon as possible. The work around dementia and how we care for older people is especially important because they are such major challenges facing health-care and social-care providers."

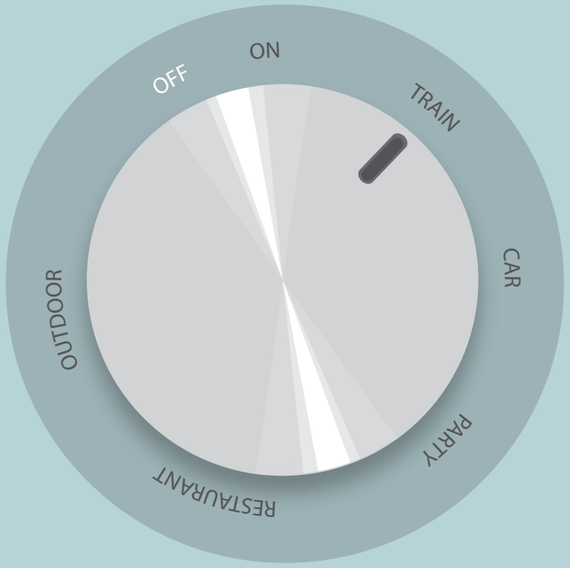
The new funding is part of a £124 million boost from the government to help ensure that patients benefit from innovative new treatments and techniques that could revolutionise future health care. It's hoped that the financial boost will also help stimulate the research economy and attract future research funding.

16.07.13
New results show that the dementia prevalence figures in the UK have declined over the past 20 years.

03.07.13
Natural ventilation technology developed by a Cambridge spin-out has the potential to halve heating bills.

13.06.13
New research suggests that public health in developing countries may be better improved by reducing illiteracy rather than by raising average income.

NOISES OFF



The machine that rubs out noise

Film available online

Future hearing aids could be adjusted by the wearer to remove background noise using new technology that could also be used to clean up and search YouTube videos.

A noisy restaurant, a busy road, a windy day – all situations that can be intensely frustrating for the hearing impaired when trying to pick out speech in a noisy environment. Some 10 million people in the UK suffer from hearing difficulties and, as helpful as hearing aids are, those who wear them often complain that background noise continues to be a problem.

What if hearing device wearers could choose to filter out all the troublesome sounds and focus on the voices they want to hear? Engineer Dr Richard Turner believes that this is fast becoming a possibility. He is developing a system that identifies the corrupting noise and "rubs it out".

"The poor performance of current hearing devices in noise is a major reason why six million people in the UK who would benefit from a hearing aid do not use them," he said. Moreover, as the population ages, a greater number of people will be hindered by the inability to hear clearly. In addition, patients fitted with cochlear implants – devices implanted into the brain to help those whose auditory hair cells have died – suffer from similar limitations.

The solution lies in the statistics of sound, as Turner explained: "Many interfering noises are immediately recognisable. Raindrops patter on a surface, a fire crackles, talkers babble at a party and the wind howls. But what makes these so-called auditory textures sound the way they do? No two rain sounds are identical because the precise arrangement of falling water droplets is never repeated. Nonetheless, there must be a statistical similarity in the sounds compared with say the crackle of a fire.

"For this reason, we think the brain groups together different aspects of sounds using prior experience of their characteristic statistical structure. We can model this mathematically using a form of statistical reasoning called Bayesian inference and then develop computer algorithms that mimic what the brain is doing."

The mathematical system that he and colleagues have developed is capable of being "trained" – a process that uses new methods from the field of machine learning – so that it can recognise sounds. "Rather surprisingly, it seems that a relatively small set of statistics is sufficient to describe a large number of sounds."

Crucially, the system is capable of telling the difference between speech and audio textures. "What we can now do in an adaptive way is to remove background noise and pass these cleaned up sounds to a listener to improve their perception in a difficult environment," said Turner, who is working with hearing experts Professor Brian Moore at the Department of Experimental Psychology and Dr Robert Carlyon at the Medical Research Council Cognition and Brain Sciences Unit, with funding from the Engineering and Physical Sciences Research Council.

The idea is that future devices will have several different modes in which they can operate. These might include a mode for travelling in a car or on a train, a mode for environments like a party or a noisy restaurant, a mode for outdoor environments that are windy, and so on. The device might intelligently select an appropriate mode based on the characteristics of the incoming sound. Alternatively, the user could override this and select a processing mode based upon what sorts of noise they wish to erase.

> "we are developing the technology to underpin intelligent hearing devices"

"In a sense we are developing the technology to underpin intelligent hearing devices," he added. "One possibility would be for users to control their device using an interface on a mobile phone through wireless communication. This would allow users to guide the processing as they wish."

Turner anticipates a further two years of simulating the effect of modifications that clean up sound before they start to work with device specialists. "If these preliminary tests go well, then we'll be looking to work with hearing device companies to try to adapt their processing to incorporate these machine learning techniques. If all goes well, we would hope that this technology will be available in consumer devices within 10 years."

Tinnitus sufferers could also benefit from the technology. Plagued by a constant ringing in the ears, people with tinnitus sometimes use environmental sound generators as a distraction. Such generators offer a limited selection of sounds – a babbling brook, waves lapping, leaves rustling – but, with the new technology, "patients could traverse the entire space of audio textures and figure out where in this enormous spectrum is the best sound for relieving their tinnitus," added Turner.

The technology not only holds promise for helping the hearing impaired, but it also has the potential to improve mobile phone communication – anyone who has ever tried to hold a conversation with someone phoning from a crowded room will recognise the possible benefits of such a facility.

Moreover, with 100 hours of video now being uploaded to YouTube every minute, Google has recognised the potential for systems that can recognise audio content and is funding part of Turner's research. "As an example, a YouTube video containing a conversation that takes place by a busy roadside on a windy day could be automatically categorised based on the speech, traffic and wind noises present in the soundtrack, allowing users to search videos for these categories. In addition, the soundtrack could also be made more intelligible by isolating the speech from the noises – one can imagine users being offered the chance to de-noise their video during the upload process.

"We think this new framework will form a foundation of the emerging field of 'machine hearing'. In the future, machine hearing will be standard in a vast range of applications from hearing devices, which is a market worth £18 billion per annum, to audio searching, and from music processing tasks to augmented reality systems. We believe this research project will kick-start this proliferation."

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Credit: St Petersburg Institute of History of the Russian Academy of Sciences

Text *and the message*

It may be a modern term, but information technology is as old as civilisation itself, and its impact on past societies was often just as profound. An ambitious project is tracing how such innovations created a complex graphic environment in Russia, during an earlier information age.

Cultural historians are hardly strangers to niche interests, but it's difficult, at first glance, to understand why anyone would want to study the history of printed blank forms. Nevertheless, part of Professor Simon Franklin's recent research has focused on just that – or more specifically, on printed blank forms in Russia, up to the mid-19th century. So comprehensive has his investigation been that Russia now has its own early chronology of printed blank forms.

'Why?' seems an obvious question. "The printed blank form is one of the great innovations of civilisation," Franklin asserted. "It's interactive – a fixed template, with variable components. Spreading in Western Europe from the late 15th century, in Russia from a couple of hundred years later, they became essential in administration and commerce. They are the direct precursors of most kinds of online transaction today."

As an historical source, the importance of the form is not the thing in itself, but the fact that it existed, the ideas it represented, and how it was used. Consider passports, for example. At face value, this particular 'interactive template' appears to be a means of crossing a border, although it is also both a mark of national identity and a symbol of state control. In Russia, however, it also had a more particular meaning. Although late to adopt print in general, Russia was the first European country to make it compulsory in regulating the movement of people within its own borders. The earliest mass distribution of printed blanks in Russia, from the 1720s, was passports for peasants.

Franklin sees such documents as examples of early modern information technologies, and his research into blank forms constitutes part of the groundwork for a much more expansive project, examining such technologies in Russia from 1450 to 1850. This initiative, which he is undertaking with Dr Katherine Bowers, aims to describe and analyse the emergence of a bewildering array of written materials as they appeared in Russia over 400 years.

In an age when IT tends to refer to computers and telecommunications, describing printed paper as information technology seems strange. In truth, both are part of a very long history. "Information technologies have been around for thousands of years," Franklin said. "You can define them in all sorts of ways, but we are interested in devices through which information was encoded, recorded, stored, disseminated and retrieved.

"Writing in itself is the most extraordinary technology. It separates the message from the messenger, and makes the word an object. Before writing, information disappeared the moment it was uttered. Writing opened fundamentally new possibilities in the way people did business, governed, administered justice, communicated, worshipped, studied, even in the way they thought."

In a similar vein, Franklin and Bowers intend to write a history of information technologies in relation to social and cultural change. To trace that across four centuries of Russian history is a huge undertaking; their sources come from places as diverse as monasteries, printing houses, libraries, archives and private collections.

Intriguingly, they are also interested in more than just written documents. The project covers every form of representation of words: coins and seals, engravings, monuments, inscriptions, embroidery, banknotes, shop signs – even graffiti. "The coach ticket or shop sign is just as relevant as the novel," Franklin observed.

By analysing the functions of such technologies in affecting the relationships between people and things, the pair hope to reveal more about changes in societal relationships at this time. Just because most Russians were illiterate does not mean that they were unaffected by written material, and by the changing technologies of its production and display. The contents could be read aloud to them; and the texts and pictures became increasingly visible, part of their surroundings, as once-empty streets became cluttered with signs, posters, print-sellers, or printed decrees from the Tsar. To an extent, everyone lived in a graphic environment, in which information was being depicted in new ways. Franklin and Bowers want to understand more about this space – what Franklin refers to as "the graphosphere" – and what it meant for the people living in it.

This is, however, more than a study of change over four centuries; it is also a fundamental investigation into how societies adopt, perceive and respond to that change. Russian history in this sense is a foil to more-familiar, Western European conceptions of technology-driven progress. Franklin argues that it offers a case study in how technology unlocks contrasting cultural responses depending on where it is used, with the graphosphere becoming a "complex ecology" of new and old technological practices. "The idea that once technology arrives something specific follows is wrong," he adds. "Something is enabled, certainly. But that's only the beginning of the story."

Roughly speaking the 1450–1850 span begins with the dawn of printing by moveable type in Europe, and ends with its mechanisation, and the spread of the electrical telegraph. Between these bookends, Franklin and Bowers can already cite numerous instances where information technologies affected Russian society in unpredictable ways, contrasting with Western Europe. For example, while printed German and Latin texts – especially Bibles – were used by scholars in Russia from the late 15th century, Russian printing itself did not begin until over half a century later, and then only intermittently and on a very small scale.

Until around 1700, almost all Russian printing was religious; and until the 19th century, almost all printing presses were owned or licensed by the State. This not only had consequences for the economics of printing (by contrast with the rapid proliferation of commercial printers in Western Europe), but also lent the technology itself an aura of official authority.

At the other end of the period, Bowers has looked at circulation and publication. Although by the 1800s one could be immortalised in print with relative ease, most Russian writers weren't interested. For most, it was far more important to write for the sake of writing, for an audience of like-minded friends. Works were disseminated in handwritten letters and drafts, in albums, through recitation at literary salons. Modern editions of the poet Pushkin, for example, are necessarily littered with annotations so that readers can understand his often inscrutable in-jokes. "The poems were mostly meant for him and his friends," said Bowers. "Until the mid-19th century, many Russian writers thought the idea of being published in print rather vulgar."

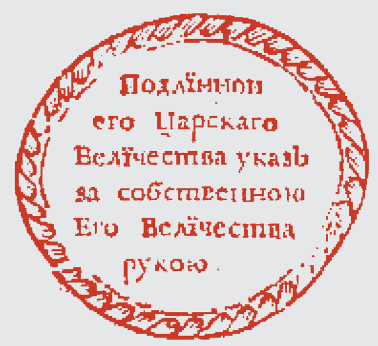
Franklin ultimately perceives a link between this history and the modern IT age. Today, of course, we are also witnessing rapid technological changes, which transform the ways in which we spend money, our interactions with others, or the extent to which we trust our governments.

As with the comparison between Russia and Western Europe, modern cultures are no less divergent in the meanings they confer on such innovations. Young people in the West are likely to attribute a very different importance to social media compared with people who used those platforms to spread their messages during the Arab Spring.

"This is about dialogue between the study of the present and the study of the past," Franklin observed. "One of the motivations for this project is that, for questions thrown up by technology in the present, there are equivalent processes to be found in the past." Perhaps more than other generations, we are well placed to perceive and understand the complicated history of the graphosphere, and of the relationship between information technologies, and society itself.

Images
Above: peasant passport, 1733
Opposite: stamps from an entry pass to the Moscow English Club, St Petersburg, 1829 *(top)*, and a decree of Peter the Great, 1715 *(below)*

"Once-empty streets became cluttered with signs, posters, print-sellers, or printed decrees from the Tsar"



"Writing in itself is the most extraordinary technology. It separates the message from the messenger, and makes the word an object"

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“The numbers get very big very quickly”

Getting schooled in the ‘noise’: *learning about learning using big data*

Brits notoriously love bureaucracy, so it’s perhaps unsurprising that the UK is a world leader in administrative data. With the digital era heralding a data revolution unlike anything in human history, education researchers such as Anna Vignoles are in a unique position to take advantage of this country’s data deluge.

According to the January 2013 School Census, 8.2 million boys and girls trudged back to 24,328 schools across England after the Christmas holidays. Some are immigrants, some royalty. Some are Catholic, some Sikh, some Jewish. Some go to private schools. Some need free school meals.

In the classroom, they are taught English, maths and science – as well as everything from the Reformation to colouring in. Their attainment levels are regularly predicted and monitored with varying degrees of accuracy – some will get straight As; some will get excluded. Most will fall somewhere in between.

And all of this information will be recorded, adding to the increasingly vast statistical reservoir of data as half a million kids complete the school system every year. Technology has allowed us to build information sets of unprecedented size and complexity, and this ocean of administrative info is the emerging coalface of education research in the era of ‘big data’.

Professor Anna Vignoles, who joined Cambridge’s Faculty of Education at the start of this year, is an economist specialising in the kind of quantitative research methods that have become possible in the wake of the big data explosion.

> “It takes years to accumulate the knowledge to analyse even one dataset, and those skills are becoming hugely important”

Buried in the ‘noise’ of these enormous administrative datasets lie important correlations awaiting detection, says Vignoles. When combined with qualitative methods, these data can provide education researchers with the kind of robust evidence needed to inform and evaluate education policy.

“The Department for Education first opened up their administrative data to the research community about 10 years ago, with fantastic results. A number of studies have used these data to look at school effectiveness or impact of resources,” said Vignoles.

“It’s partly through analysis of these data that we found the massive socio-economic gap at the point of entry into the school system actually worsens through primary. A lot of universities now aim outreach activities at primary schools as a result.

“Combined with further education data, you have a timeline from the beginning of primary education right through to graduation, with the potential to go further by looking at figures like early career salaries,” said Vignoles. “Just the admin data alone has transformed what we’re able to ask in terms of understanding pupil achievement.”

It’s not just connections within certain datasets. By cross-referencing different data streams, researchers will be able to uncover connections and inferences between income, health, education, age, ethnicity and biomedical information.

One of the next projects for Vignoles, for which – along with her Faculty of Education colleague Professor Diane Reay – she is a co-investigator, will be the ambitious ‘Life Study’. The project will start gathering data during pregnancy on everything from blood type to economic situation from a cohort of just under 100,000 mothers and their children. It will amount to the largest study of its kind ever done and, when combined with existing datasets, will provide researchers with an unparalleled overview of the lives of British citizens.

“It’s a massive undertaking,” said Vignoles. “Clinics need to be built to provide space for interactions and testing, which is under way, and some field work will start next year.

“UK cohort surveys are probably the best in the world. We have data on children born in 1946, 1958, 1970, the millennium – and now going into 2015. There’s no other country where you can have lifetime data on children born a generation apart going back to the forties.”

The NHS is the spider at the centre of this data web, with its “highly administered, centralised system” that produced the original longitudinal cohort datasets. “When the US attempted a very large-scale study of this kind it proved highly problematic because it’s a very fragmented, private system,” said Vignoles, “whereas the UK has centralised, manageable systems that provide rigorous administrative data which, when linked with survey data, is just incredibly powerful.”

For Vignoles, Cambridge has got an important head start on other institutions when it comes to big data research in the social sciences: hardware. “You need to look at multiple cohorts when it comes to this kind of social science research, and the numbers get very big, very quickly. Cambridge’s investment in the physical sciences means that we have the kind of huge computing capacity that you need – such as the Darwin supercomputer run by the High Performance Computing Service.”

But hardware will only get us so far, says Vignoles. Social sciences in particular need to work hard at building the capacity in people – the skills and a “lack of fear” of the numbers, as many of these disciplines have traditionally focused on qualitative methods, and the big data explosion will require a “shift in emphasis”.

“It takes years to accumulate the knowledge to analyse even one dataset, and those skills are becoming hugely important, whether you’re a historian, economist, geneticist or sociologist. We need more people with the skills for this kind of work, and one of the big pushes here at Cambridge is to build quantitative capacity in terms of people.”

Vignoles highlights the need for balance between both qualitative and quantitative research. “We have to be sensible in our recommendations of what should be measured, but also recognise why we’re measuring it in the first place. There’s an awful lot of evidence that children do better when they have assessment and feedback on what they do, and at the system level you can’t rely on everyone doing their thing and hope you will get a system that’s efficient.

“Some degree of monitoring is part and parcel of any system. These big data sets and the number crunching involved offer efficient and effective ways to develop and improve the UK education system. Some of it’s about accountability, but also understanding – you can’t tell what’s happening to a particular group without looking at it. We wouldn’t have known about the success story of many non-white children in the system, for example, without the data analysis.

“I’m convinced that the projects we do going forward will not be discipline based. We will increasingly have to approach research questions with people from different backgrounds – that means multidisciplinary, it means multi-method, and I think the work will be much better for it. Cambridge, being so strong across a range of disciplines, can – and should – lead the world in such approaches.”

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Image
Human cytomegalovirus

Silent Killer

Many of us are infected with a virus we'll never clear. While we're healthy, it's nothing to worry about, but when our immune system is suppressed it could kill us.

To catch the herpes virus human cytomegalovirus (HCMV) you must be exposed to someone who has it. This isn't difficult: it is carried by around 65% of the population. Once in the body, HCMV persists for life owing to its clever ability to avoid our immune system and to go into hiding inside our cells in a latent state. Now, research is identifying changes in these cells that could lead to a new route to eradicating the virus.

"HCMV can be acquired very early in childhood, and the number of people infected gradually rises throughout life," said Professor John Sinclair, a molecular virologist in the Department of Medicine. "The active virus can not only be passed from an infected mother to her child in breast milk but can easily be transferred from child to child in saliva – one child puts a toy in their mouth, then it's passed to another child who does the same, and the virus is passed on. It's also a sexually transmitted disease, so there's another increase in infections when people become sexually mature."

Once acquired, the virus goes into a latent state in the body. If it reactivates in healthy people, their immune responses prevent it from causing disease. But when the immune system is suppressed, active HCMV becomes dangerous. It is a major cause of illness and death in organ and bone marrow transplant patients, who are given drugs to deliberately suppress their immune system and prevent their body rejecting the transplant. With an increasing demand for transplants in the UK, HCMV is set to become a growing problem.

"If it's not treated well, or it develops resistance to antiviral drugs, HCMV can lead to pneumonitis – inflammation of the lung tissue – and, in the most extreme case, it replicates all over the body and the patient ends up with multiple organ failure," said Dr Mark Wills, a viral immunologist working alongside Sinclair in the Department of Medicine.

"Tissue from donors carrying the virus often has to be used for transplants because there are so few donors and so many people carrying the virus," said Sinclair. "By transplanting bone marrow, or an organ from someone with the infection, you're giving the patient the virus and you're immune-suppressing them. That's the worst of both worlds."

And HCMV is a worry not just for transplant patients. "HCMV is now the leading cause of infectious congenital disease – that is, disease present at birth," said Sinclair. Women in early pregnancy who are newly infected with HCMV or whose HCMV reactivates are at real risk, and this can lead to disease in their unborn baby. HCMV also targets HIV-AIDS patients, where a progressive failure of the immune system allows this opportunistic infection to thrive.

There is no vaccine to prevent HCMV infection, and the antiviral drugs available to treat it have significant toxicity and only limited effectiveness. In addition to the problem of viral resistance, drugs can only target HCMV in its active state, which means the virus can never be fully eradicated. "You can suppress the virus down to a very low level, but you can never get rid of the latent reservoir with the currently available antiviral drugs," said Wills.

Sinclair and Wills, who have just received their fifth consecutive five-year grant from the Medical Research Council (MRC), have focused on understanding how the virus maintains this latent infection in specialised cells of the immune system and how the immune system is prevented from eliminating the virus from the body.

"The belief has always been that, in its latent state, HCMV was just sitting there doing nothing, waiting to reactivate," said Sinclair. "But we've started to identify major changes in latently infected cells, and we think these are targetable with novel drugs and immunotherapies.

"One change is in a transporter protein normally used by the cell to pump out things it needs to get rid of," he added. "If you put the chemotherapy drug vincristine on a healthy cell, the cell will pump it out and survive. Working with Paul Lehner at the Cambridge Institute for Medical Research we found that, during latent infection, this transporter protein is less effective, making the cell more prone to killing by vincristine." Their results were published in *Science* in April 2013.

"In addition to treatment with drugs, we're looking into immunotherapies – treatments based on using the patient's immune system," said Wills. "Clearly, the difficulty is that all healthy people have very good immune responses to the virus, yet we all still carry it and can never get rid of it. There must be a problem here – the virus is deliberately trying to evade the immune system by manipulating it."

Sinclair and Wills are trying to understand how the virus does this while in its latent state. Their findings show that HCMV disrupts the proper activation of the immune system by manipulating small signalling molecules called cytokines and chemokines, which normally help to kick-start the process of removing a foreign invader. "Now we know this, we can start to think about intervening," said Wills.

"We've also found that latently infected cells are producing a number of viral proteins," added Wills. "That's a dangerous strategy for the virus, because these proteins could be presented on the surface of the cells they're hiding in, which would attract immune cells like T cells to kill them. Our initial research showed that there are T-cell responses – so why aren't the viral cells being eliminated? It's paradoxical." In further investigations, they uncovered another mechanism in which the virus was promoting a certain subtype of T cell that suppresses the immune system. "So now we're working to remove the immunosuppressive component of that immune response by either removing or neutralising the function of the immunosuppressive T-cell subtype, to enable the other components of the body's immune response to target the infected cells," added Wills.

By targeting latent infection, this work holds great promise for developing better methods of treatment for HCMV and for the design of a vaccine. "If you intervene just before a transplant, and use this immunotherapeutic technique to target the latently infected cells, in combination with the drugs, you can purge the infected cells," said Sinclair. "This massively reduces the potential that HCMV will reactivate in the person receiving the transplant, because effectively you're not giving them the virus," he added.

They have proved this concept in the laboratory and their new MRC grant will enable them to trial its effectiveness in a model system as a stepping stone to human clinical trials. "A decade ago we couldn't have even contemplated doing this type of work," said Sinclair, "but now we have worked out what's going on during latent infection, we can try to target these changes. Being able to clear the latent infection is key to eradicating much of the disease caused by HCMV that we see in the clinic."

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"The virus is deliberately trying to evade the immune system by manipulating it"

FROM CATTLE TO CAMELS

A move from cattle herding to camel keeping among Kenyan farmers is more than an economic transition, it represents a fundamental shift in age-old customs.

It's a long and bone-shaking drive from Nairobi to the Marsabit County of northern Kenya. It's an arid landscape, prone to drought, with dusty lowlands leading up to forested volcanic highlands. The thousands of people who make a living from the land here – among them the Boran and Gabra – are pastoralists. For as long as anyone can remember, they have moved with their livestock, following the rain to find grazing.

In 2012 Dr Elizabeth Watson, a human geographer who specialises in eastern Africa, spent a month carrying out fieldwork in Marsabit. It wasn't her first trip to the region: she trained as an anthropologist and an earlier study of the relationship between landscape and ritual had brought her into contact with the Boran and neighbouring groups. She returned last year with a more specific set of objectives: to understand why the Boran people, whose culture has been traditionally tied to cattle herding, are now turning to camel keeping.

She said: "Camels were by no means unknown to the Boran but they were always considered inferior by people whose daily lives are linked to the cattle which provide them with milk, meat, ritual goods and trading opportunities. Boran identity is so strongly connected to cattle that it is often said that 'to be Boran is to have cattle', and some observe a taboo that forbids them from saying the word camel, which they describe as 'the long-necked thing'."

Yet, whereas cattle are demanding in terms of their needs for water and fodder, camels have an extraordinary ability to survive for a long time without water and to live on harsh scrub vegetation, and they produce rich, nutritious milk over long periods.

"Faced with increased aridity and pressures of food security, the Boran people began investing in camels as an alternative or addition to cattle around 16 years ago," said Watson, whose research was funded by a Thesiger Oman International Fellowship and the Royal Geographical Society with IBG. "An investigation into how people negotiate such a profound change of lifestyle forms one of the chief strands of my fieldwork. There's an assumption that pastoralists, who are seen as being highly traditional, will be resistant to change. In fact they are highly flexible and pragmatic. People spoke to me warmly about the advantages of camels over cattle. And when I asked them how they would pay for brides, they said they would sell a camel to buy cattle so that the ritual would be upheld. It's an interesting example of people's ability to adapt to changes and embrace opportunities."

While cattle herding took the Boran on long treks to distant water points in times of drought, camels are happy to live near or in town where they feed on the liquid-rich euphorbia hedges that surround many compounds. "One man said he hadn't taken his camel to water for three years. Proximity to town gives herders access to a ready market for milk and they are able to sign contracts with shopkeepers and café owners," said Watson. "We also found that while the milking of cattle was one of the duties carried out by women, both men and women were involved in milking camels."

Camels bring new challenges as well as advantages. There are few vets in rural Kenya and camels suffer from a range of diseases, some of which can affect humans. Watson said: "While some people said that their camels were flourishing, others said that their animals had become sick and had died. There was a lack of knowledge and medicines to treat them. Certain breeds of camel are more suited to harsh, rocky areas than others, something not always understood by the development organisations who, seeing the new preference for camels, have started to give them out as a form of restocking.

Watson's work will not only inform NGOs but also provide much-needed information about the challenges faced when a society adapts to pressures such as the need for food security.

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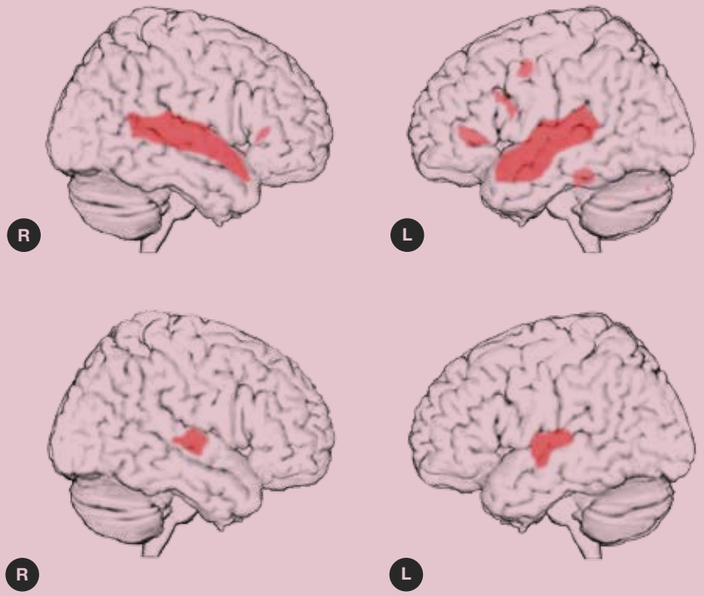

Image
Areas highlighted in red on these pictures of the right and left hemisphere of the brain show the frontal and temporal brain networks involved in the processing of linguistic *(above)* and paralinguistic *(below)* information in intonation

Tuning into the melody of speech

In a groundbreaking new study, Cambridge researchers have mapped out the neurobiological basis of a key aspect of human communication: intonation.

If you were to read out loud the words, "I'm absolutely delighted that Kate blamed Paul and Tessa Arnold" in a flat voice, with no rises or falls and placing equal weight on each syllable, you would quickly demonstrate the fundamental importance in human communication of intonation. Is Kate blaming Paul, while Tessa blames Arnold? Or is Kate blaming the Arnolds: Paul and Tessa? It would also be difficult to tell whether the speaker really is delighted, or whether they are being sarcastic. You would have suppressed a natural tendency to vary how high or low your voice is (pitch), to stress particular syllables, to hesitate where you would expect commas (rhythm), and to convey emphasis by varying volume. All of these elements constitute intonation.

Dr Brechtje Post of the Phonetics Laboratory in the Department of Theoretical and Applied Linguistics describes intonation as "the melody of language". "It signals," she explained, "how the speech stream is structured and what category of statement you are making. The word *now*, for example, can signify a question or an answer depending on intonation."

However, intonation also signals how we feel. Different intonation patterns for *now* can also express emotions such as triumph or frustration. "We call this function 'paralinguistic'," said Post. "It is thought to result from our primate inheritance, reflecting biologically driven codes that are now exploited to express attitudes and emotions universally across the languages of the world. It is distinct from the linguistic use of intonation, which is language specific."

Since the linguistic meaning and the emotions of the speaker are conveyed by the same acoustic signals – mainly pitch – linguists have struggled to disentangle the relationship between them. "Linguists have long theorised that linguistic and paralinguistic information are crucially different, but evidence has been elusive," said Post. "This suggests that they would have to be processed differently in the brain, but this had not been shown either – until now."

With funding from the Economic and Social Research Council, Post and her co-investigator, neuroscientist Dr Emmanuel Stamatakis, conducted a four-year study combining experimental tasks with the latest MRI brain-scanning techniques. Native English-speaking participants within a specific age cohort were scanned while hearing test words and giving a yes/no response to either a linguistic question: 'Does this sound like a statement?,' or a paralinguistic question: 'Does this sound surprised?.' Distinct areas of their brains activated according to whether they were processing linguistic or paralinguistic meaning.

The researchers did indeed find that different frontal and temporal brain networks in both hemispheres contribute in different ways to the processing of intonational information.

"The network which is engaged in the linguistic interpretation of intonation is the same as that which supports abstraction and categorisation for other types of linguistic information, such as recognising consonants and vowels," said Stamatakis. "We did not, however, expect the degree of overlap between these networks or that processing paralinguistic information involves a much more limited network."

These findings confirm that neural processing of linguistic information in intonation is distinct from emotional or attitudinal information. This insight will aid the understanding of speech and comprehension deficits following, for example, stroke, and may have potential applications in speech therapy. As for the implications for understanding intonation, the findings show that it is not merely a side effect of biological imperatives related to animal communication (for example, a high squeaky sound being associated with danger), but that at least some of it is integral to the structure of human language.

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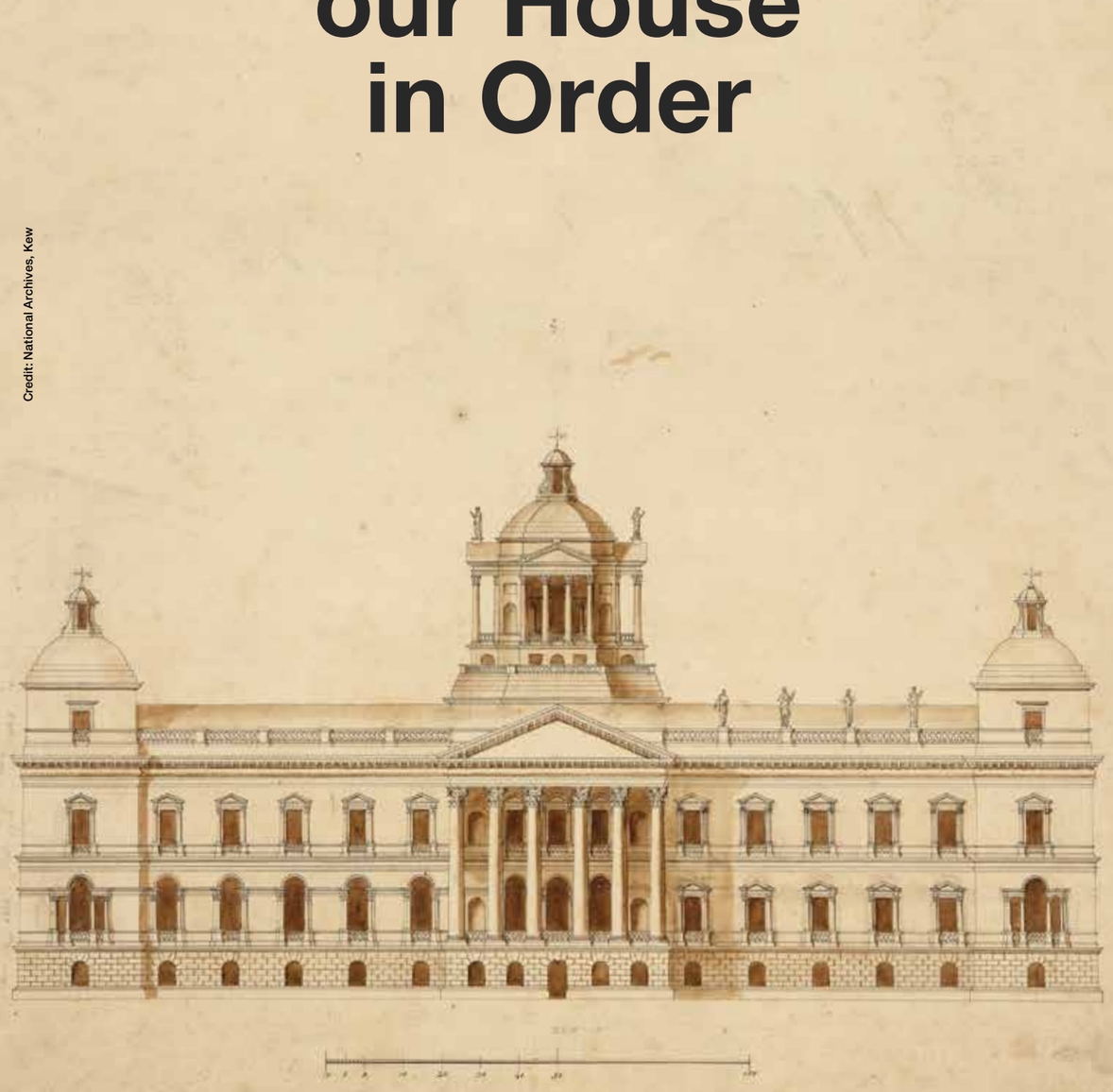
With the Houses of Parliament requiring costly renovation, new research suggests we may have something to learn from plans in the 1730s to rebuild the Palace of Westminster.

Image
'Belvedere' Proposal by William Kent, 1739

Film available online

Putting our House in Order



Credit: National Archives, Kew

It was a decade that has some resonance for contemporary London. At the end of a 20-year building boom, London was sprawling outwards and soaring upwards. Its skyline was punctuated by imposing new structures juxtaposed with ramshackle old buildings – including the rambling, crumbling Palace of Westminster. So in 1733, William Kent, influential landscape gardener, designer and architect, was commissioned to design a more spacious and convenient "Edifice that may be made use of for the Reception of the Parliament."

Over the course of the next decade, Kent submitted a succession of plans ranging from a complete rebuild to a salvage operation. They came to nothing. By 1742, the coffers had been drained by war with Spain and British embroilment in the War of Austrian Succession. Kent's political champion, Prime Minister Robert Walpole – advocate of the Palladian style of architecture appropriated by the Whigs to articulate the values of order, reason and clarity to which they aspired – was toppled.

But Kent's legacy of 80 drawings, suggests art historian Dr Frank Salmon, might in some respects represent the best Houses of Parliament the 'Mother of all Parliaments' never had. Salmon's analysis of these meticulously drafted documents has, moreover, led him to revise his convictions about good public architecture, and its perception in Georgian Britain.

"Unusually for a Royal commission, there are few supporting documents save for two letters from the Office of Works," explained Salmon. So the research required close interrogation of the drawings themselves, which are dispersed over four sites in London. "A lot of the work involved measurement: the architect, after all, will have been thinking in three dimensions, in the context of how the building will fit onto the ground."

So what can we glean from Salmon's reconstruction – and deconstruction – of Kent's symmetrical arrangements of Corinthian columns, pediments, Venetian windows, white Portland Stone rusticated ground floors and imposing first floors that typify English Palladianism?

To an extent that has challenged Salmon's conception of attitudes to preservation in the 18th century, Kent's Houses of Parliament would have been charged with symbolism in a way we tend to associate with a late 19th-century concern with loss of heritage. "In most of his schemes, Kent retained the ancient Court of Requests," said Salmon, "a medieval foundation that gave people instant access to justice without great cost. It had ceased to function during the Civil War, so he was introducing to a new building a redundant institution which, in one set of plans, would have been almost as big as the Hall of Mirrors at Versailles. Lost to us now, it must have symbolised something cherished about British liberty."

"In the first scheme, the book collection that today forms the nucleus of the British Library was to be an integral part of the building. Again, the idea of the nation's intellectual capital being co-proximate with its centre of power is redolent with symbolism."

Although too small to accommodate today's Parliamentary business, Kent's building would nevertheless have been imposing. At 444 ft long and parallel to the River Thames in one plan, its towering columns and dome would have dominated the city. In a later plan, with a huge central tower, it would have projected far enough into the Thames to require embankment. It would, for the first time, have presented the home of government as a unified entity.

At a time when the Commons was beginning to sit along party lines, "Kent's Commons would have been amphitheatrical, although he retained the biaxial Lords," said Salmon. "In one plan, a section of seats was angled, perhaps set aside for the Cabinet." In what seems a strikingly literal assertion of authority, the Speaker's throne protruded into the middle of the Chamber. There would have been space for spectators; although, with a ban on Parliamentary reporting in the press reinforced in 1738, the purpose here is opaque.

London was sprawling outwards and soaring upwards. Its skyline was punctuated by imposing new structures juxtaposed with ramshackle old buildings

Unlike Westminster today, where the labyrinthine corridors of power would stretch to three miles if placed end-to-end, Kent's building would have been relatively easy to negotiate. Its classical proportions and suites of adjoining rooms would have made a virtue of light and space – for some: Salmon has discerned designs for communal toilets for male servants, in contrast with comparatively more luxurious accommodation above stairs.

If Kent's existing Horse Guards building is anything to go by, his Parliament would have been relatively sustainable compared with today's building, which presents a 'looming crisis' according to a recent Parliamentary Report, ridden with asbestos, with antiquated heating and drainage, and sinking into the ground.

As for Kent the architect, Salmon's research represents a substantial reappraisal of Kent's position in our cultural history. The exuberant, erratic parvenu of some depictions comes across as "a highly professional, competent architect rooted in reality", according to Salmon, positioning facilities with a view to the paths that the myriad personnel who make up the ecology of parliament would need to trace through the building. Perhaps Kent's charming habit of doodling in the margins of his plans the parliamentary personalities who populated his imagination helped make his architecture sympathetic to those who would inhabit it.

The plans evolved in a way that suggests that Kent was responsive, too, to the changing skyline. "Hawksmoor's towers of Westminster Abbey were being built, and Archer's St John's, Smith Square, had been recently completed," said Salmon. "Kent's initial plan for a dome wouldn't have held its own. So we see Kent introduce increasingly spiky structures: an interesting melding of a pictorial notion of the gothic steeple, rendered in classical form."

Four years in the company of William Kent has led Salmon to re-evaluate his position on Palladian architecture – the style inspired by architect Andrea Palladio's interpretation of classical Greek and Roman architecture. "I wanted to do this research to test my hypothesis that the Palladian style, so successful for country houses, was a dull subspecies of public architecture imposed on the country by the influential Lord Burlington and his friends. Kent's Horse Guards building, for example, is really a version of a country house. When you consider its design in functional terms, however, of where the horses, foot soldiers, the ordnance, the barber, the coffee shop, the clerks would be situated, it all works perfectly, horizontally and vertically, in terms of the distribution of spaces. It seems that the way in which we have come to regard city and country as stylistically distinct as well as functionally so did not apply in the 18th century."

"With historical research, it's always good to have your hypothesis challenged by the evidence, because you know you're nearer to the truth."

Salmon's research has recently been published by Yale University Press as part of a major retrospective on William Kent in the context of the tercentenary of the Hanoverian succession. Publication coincides with a substantial exhibition of Kent's work at the Bard Center New York, which will move to the Victoria and Albert Museum in Spring 2014.

Pallid Palladianism or classy classicism? Members of the public will be able to assess for themselves the grand designs that would – architecturally – have brought a sense of proportion to Parliament.

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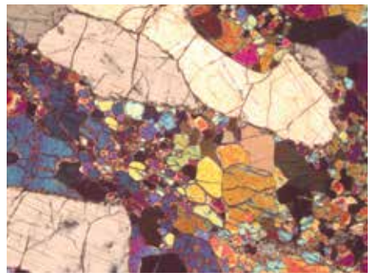


Images
The Sedgwick Museum of Earth Sciences' petrology collection

Feature article and film available online

Study of a unique rock collection – and its astonishingly beautiful microscopic crystal structures – could change our understanding of how the Earth works.

If it was possible to drill to the centre of the Earth, the largest part to traverse would be the mantle. Although solid, this complex mix of minerals is capable of flowing, albeit over long timescales, as a consequence of the massive variations in pressure and temperature to which it is subjected.

Studying these deep layers is crucial to understanding the inner workings of our planet and the driving forces behind the movement of tectonic plates. Molten parts of the mantle feed volcanic eruptions and supply the cocktail of chemical elements required for the maintenance of a habitable planet.

Now, a new study funded by the Natural Environment Research Council in the University's Department of Earth Sciences has turned to a unique rock collection within its Sedgwick Museum to provide fresh understanding of the mantle's composition.

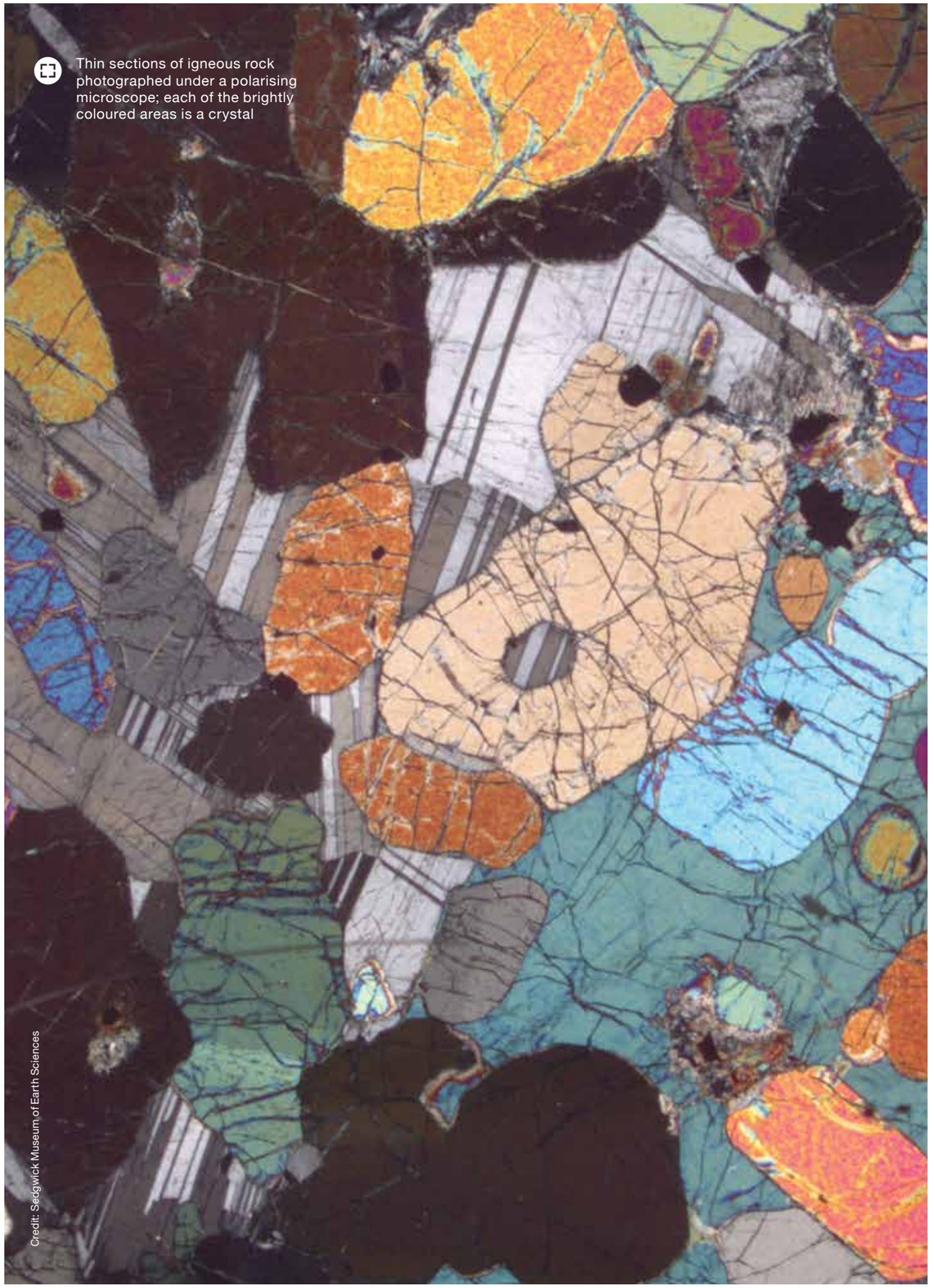
The collection dates back to at least the early 1800s and now contains around 160,000 rocks and about 250,000 slide-mounted rock slices that are thin enough to let light through. "The rocks we are interested in are igneous – the frozen remains of molten rock formed at depths of 100 km or more from the mantle and then spewed out of volcanoes," explained project leader Dr John Maclennan, who is working with Dr Arwen Deuss and Dr Tim Holland. "They carry a message about the composition of the deep Earth that we can decrypt using rock chemistry."

By marrying together this geochemistry with seismic data, the researchers hope to arrive at the most comprehensive assessment of mantle structure to date.

"The collection presents a wonderful opportunity to improve our knowledge of the mantle's structure, and how this links to the planet's habitability," added Maclennan. "And study of it may also provide long-term benefits to the UK economy in terms of better understanding of energy or mineral resources."

The Sedgwick Museum of Earth Sciences holds fossils, rocks and minerals from around the world that cover more than 550 million years of Earth's history.

www.sedgwickmuseum.org



Thin sections of igneous rock photographed under a polarising microscope; each of the brightly coloured areas is a crystal

Credit: Sedgwick Museum of Earth Sciences

The Science of Saving Venice

Image
The Doge's Palace, Venice, painted in the 18th Century by Giovanni Canaletto

Credit: ©The Fitzwilliam Museum, Cambridge

How will regions around the world adapt to an increase in sea levels? A project looking at how Venice can manage its rising waters is a remarkable case study for flood-prone environments elsewhere.

When Canaletto immortalised the waters of the Venice Lagoon beneath the steps of the Doge's Palace almost three centuries ago, he depicted water levels that have long been surpassed. Today, the water sometimes laps at brickwork above the protective stone foundations on many of the buildings and the frequency of flooding of this World Heritage Site is increasing.

A significant fraction of the world's coastlines is thought to be under threat over the next century from rising sea levels caused by climate-change-related melting of snow and ice, and thermal expansion of the oceans. How should regions plan, and how much time do they have?

One way that Venice – a city with more than five centuries of flood experience – is protecting itself is through the ongoing construction of huge barriers with hinged steel gates to seal off the three inlets that connect the Lagoon with the Adriatic Sea at times of very high water. In addition, soft engineering approaches such as replacing lost salt marshes have also been undertaken.

> "Environmental sustainability can only be a 'whole-Lagoon' concept"

But, as for other regions of the world, the challenge is not one of simply trying to lessen the surge of sea water, as Professor Paul Linden explained: "Venice is a moving target. The city is sinking because of overuse of groundwater and because rerouting of rivers that once carried sediment has caused the Lagoon to deepen. Dredging to allow the passage of cruise liners stirs up sediment polluted by industry. The local ecosystems are under threat and this will be exacerbated if rising sea levels increase the salinity of the Lagoon.

"There is a growing recognition that the biology, physics and chemistry of the area are interconnected and that environmental sustainability can only be a 'whole-Lagoon' concept," added Linden, whose own research interests lie in the physics of water movement and how this is affected by climate change.

This holistic view has underpinned the work of the Venice Sustainability Advisory Panel, a 10-strong international group of scientists led by Linden and co-investigator Professor Charles Kennel (UCSD Scripps Institution of Oceanography). At the request of the Venetian authorities, the Panel worked on the question of what's needed to manage the waters and ecosystems in the Lagoon sustainably.

The team examined assessments of the ecology and physics of the Lagoon – from monitoring of habitat destruction and sediment loss through to the deepening of the Lagoon and the movement of currents – and they looked at the adequacy of current monitoring and modelling systems.

"Science was not enough," said Kennel. "It was equally crucial to take into account the social, economic and political considerations bearing upon Venice's decisions about the Lagoon."

"Venice has the talent and technology to manage this change adaptively," added Linden. "We needed to get some understanding of the capabilities and the gaps, and whether predictions are being made as to how the system will behave in the future. One of our major recommendations is the need for periodic assessments of the state of the Lagoon, and a means to ensure feedback between environmental assessments, policy decisions and management actions."

To help, they have created a 'vulnerability grid' to aid the authorities in planning a sustainable future, taking into consideration how rapidly the Lagoon is deepening, and how hot, dry and stormy the climate becomes. "The barriers might have a 100-year lifetime but what will Venice be like in 2100? We can't know for sure but the vulnerability grid can help decision makers translate assessments into vulnerabilities, and understand on what environmental trajectory the Lagoon is moving."

With the project now completed, Linden hopes that the Panel's ideas and recommendations will feed into the next set of decisions about how the flood barriers and the water flow in the Lagoon are managed once the gates are operational.

"Venice and its Lagoon illustrate the complexity of the sustainability issue and the trade-off between economic development and safeguarding the environment: any management plan first has to start with the question of what we are trying to sustain," said Linden. "Cities worldwide are strengthening their preparations against sea flooding. Each must develop its own adaptation strategy but in many ways Venice can be regarded as a 'laboratory' for activities aimed at coping with climate change and sea level rise. Venice could lead the way in connecting interdisciplinary science with practical use."

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Cambridge Forum for Sustainability and the Environment

Researchers have joined forces to examine how we can respond to some of the most pressing global sustainability challenges, as Professor Lord Martin Rees and Professor Paul Linden, respectively Chair and Director of the Forum, describe.

The world is changing. The rising world population, declining resources and changing climate are reshaping where we live and how we live.

On a global scale, we need to find a way in which seven billion people, expected to rise by another billion by 2030, can live a high quality of life that is less demanding on our planet. And to adapt, be efficient and sustainable, we need to know where to place our energies to mitigate the coming challenges. This requires knowledge from many different sources.

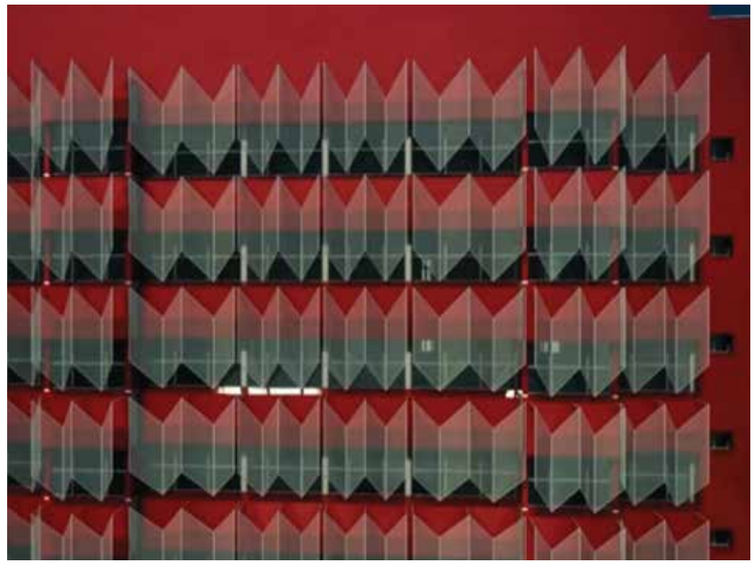
> "Sustainability is a cross-cutting challenge"

Earlier this year, 20 of the University's leading experts in energy, biodiversity, public health, anthropology, architecture, economics and other areas came together to form the Cambridge Forum for Sustainability and the Environment. A huge amount of research being undertaken at the University has a direct relevance to understanding the sort of adaptive measures that might be taken to build resilience in a changing world, and the Forum provides a space to make connections across these areas.

The first topic for discussion is 'Cities', and the increasing demographic transition from rural to urban. Information sharing across the Forum will culminate in a set of briefings to identify where there might be consensus, where there are knowledge gaps and where emerging research priorities might fill them. In March 2014, the focus of the Forum will shift to 'Balancing biodiversity, energy, water and food security'.

By its nature, environmental sustainability is a cross-cutting multidisciplinary challenge that requires the input of minds from all fields to provide the expertise that will help society make responsible decisions for the future. The Forum's role is to provide the opportunity for stimulating these cross-disciplinary conversations.

www.cfse.cam.ac.uk



Scrubbing Up:
Preparing hospitals for climate change

Innovative designs for retrofitting the vast NHS estate to stem rising carbon emissions and adapt hospitals to perform through a changing climate are being created through a multi-university collaborative effort.

"The scale of the problem is huge. We have until 2050 by the obligations under the Climate Change Act to get our emissions down by 80% from what they are now, and we don't know how to do that."

These words, spoken by Paul Morrell, former UK Chief Construction Advisor, spell out the challenge the NHS faces in attempting to reduce the 18 million tonnes of CO_2 it is responsible for producing every year – around 3% of the entire annual UK emissions – by its 28 million m^2 of buildings.

It's a challenge that has taken on a new urgency. As summers are predicted to warm, hospitals are under pressure to reduce the risk of overheating, particularly in the sort of heat waves the UK experienced in 2003, 2006 and 2009, because of the associated increased mortality rates.

"Faced with more frequent hot spells, NHS acute hospital trusts may turn increasingly to air conditioning," said Professor Alan Short from the Department of Architecture. "But such energy-intensive strategies would have a disastrous effect on the national carbon reduction programme. It's a double whammy: the pressure to reduce energy consumption colliding with the pressure to protect patients and staff from overheating.

"The last government's plan was to replace the NHS Estate with a suite of new hospitals but the 2008 economic collapse put an end to that. And that means turning back to the existing estate. How can we make the best use of the stock we've got to make it fit for purpose?"

The answer, Short believes, is to be found in the innovative low-energy design strategies that have been developed as part of the recently completed Design and Delivery of Robust Hospital Environments in a Changing Climate (DeDeRHECC) project that he has been leading. The collaborative team included researchers from the Universities of Cambridge, Leeds and Loughborough and the Open University, and was funded by the Engineering and Physical Sciences Research Council with support from the Department of Health.

"Our adaptation schemes are based on passively driven natural ventilation and cooling, operating in well-insulated buildings. They provide greater resilience to increasing temperature, mitigate carbon emissions and can be provided at a cost that is completely in line with NHS refurbishment costs."

To begin, researchers at Loughborough fitted sensors to carefully selected types of NHS buildings to monitor the inside temperature over the course of two years, creating what they believe is the largest database of environmental data on non-domestic building stock collected in the UK since the 1980s. These data, together with UK Climate Impacts Programme predictive databases, were used to calibrate computer simulation models to predict internal temperatures in 2030, 2050 and 2080 for various adaptation options in the case study hospitals.

Although the NHS estate is vast, it comprises a small number of recurring building types, as researcher Dr Alistair Fair in the Department of Architecture described: "You can see the same types of buildings occurring again and again and NHS Partner Trusts were chosen to yield a good cross section."

The project's four participating NHS Trusts were Cambridge University Hospitals NHS Foundation Trust (Addenbrooke's Hospital), Bradford Teaching Hospitals NHS Foundation Trust, West Hertfordshire Hospitals NHS Trust and University Hospitals of Leicester NHS Trust. For each, representative categories of space were examined – non-clinical, patient rooms, diagnostic, treatment and open wards.

Addenbrooke's Hospital has a medium-rise ward tower of a type one can see in at least 50 other NHS sites. The study shows that this tower is barely resilient to current hot conditions, and then only as a result of uncontrolled air leakage. "In winter, it is an epic NHS gas-guzzler," said Short.

"Even with relatively modest adaptations, much can be achieved, and a combination of sunshades for the windows, naturally driven cross-ventilation and stack-driven exhaust systems to flush the heated air would alleviate temperatures without increasing the fuel bill," he added. The stack technology required to determine airflow routes to single spaces was devised with the help of the Pathogen Control Engineering Institute at Leeds, and is effective in reducing airborne cross-infection risk within the hospital – an essential prerequisite of any adaptation scheme.

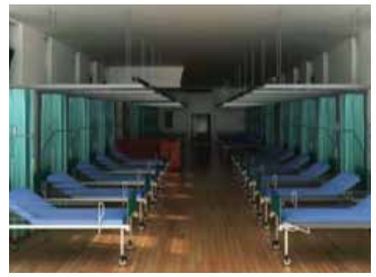
One of the most resilient hospitals to increasing temperature is one of the oldest. Bradford Royal Infirmary was built around the Nightingale ward: long thin wards arranged with beds facing each other to Florence Nightingale's very specific dimensions. "The potential resilience is a result of the heavy-built brick fabric of the building and high ceilings, which need to be coupled to intelligently controlled ventilation. Our analysis shows the revival of Nightingale's cross-ventilation scheme is enough to maintain this resilience through to 2080," said Short.

Now the team is converting research findings such as these into 'off the shelf' construction designs that can help Trusts and policy makers decide whether to decommission buildings, invest in relatively minor interventions or contemplate more substantial interventions for longer term resilience.

"All of our case studies show that we need environmentally responsive design. It is a mistake to rely on gluing renewable technologies to 'business as usual' buildings. These adaptive ideas yield easy wins – grounds both for optimism and action."

Film available online

"These adaptive ideas yield easy wins – grounds both for optimism and action."



Images
Hospital retrofitting strategies that use sunshades, insulation and natural ventilation; images shown are models created by the DeDeRHECC project

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When building for the future means what it says

In the Department of Engineering's Centre for Sustainable Development, researcher Maria-Christina Georgiadou is asking how the construction sector can ensure that domestic buildings are zero carbon over the long term.

With approximately 40% of its buildings built before 1944, the UK has one of the oldest and least efficient domestic stocks in Europe, accounting for around 25% of its carbon emissions. By 2016, however, all new homes must achieve a zero-carbon status according to government proposals. Buildings of the future should be low energy, sustainable and able to respond to future changes – climatic, technological, social or regulatory – in other words, be 'future-proofed'.

"However, there is conceptual confusion on what 'future-proofing' is. Little research has been carried out on identifying design approaches that adopt a long-term perspective in the context of the energy design of housing developments," explained Georgiadou, who has been analysing the issue with Dr Theo Hacking and Professor Peter Guthrie.

"there is conceptual confusion on what future-proofing is"

Through following four 'best-practice' housing developments in the UK and Sweden, Georgiadou has found that the focus for new buildings has predominantly been on energy-efficiency measures and mitigation of carbon emissions now, and not on strategies to address the increasing frequency and severity of temperature extremes that may lead to overheating in the future. A 'knowledge map' she has created can be used in any decision-support context for the energy design of residential buildings.

"It's the ability to respond to upcoming changes that defines future-proofing," said Georgiadou. "This must be at the heart of strengthening building codes and energy-related standards at the start of the energy design process if we are to increase the likelihood of dwellings remaining 'fit for purpose' under a set of plausible energy futures. This would be a shift away from the short-term mindset that still dominates design and construction practices."

Feature article available online

The Shape of Things to Come

"This will fundamentally change scale and location decisions for factories to the point where they will be so advantageous that people will want them at the end of their street"

Researchers are providing a vision for creatively rethinking how the manufacturing industry can perform sustainably in a changing world.

In the late 18th and early 19th centuries, industrialisation swept the globe and changed it forever: humanity mastered the art of transforming the world's raw materials into the 'stuff of the world'. Today, everything around us, from the cars we drive, to the goods we own and the clothes we wear is largely the product of industrial manufacturing.

But industrialisation also had an unintended effect on the global environment – contributing to the increasing burden of carbon emissions, pollution and waste – and it's widely accepted that a new 'green' industrial revolution is urgently needed.

"It's clear that current processes cannot be sustained indefinitely," said Professor Steve Evans. "As well as the environmental effects, the world has a finite amount of natural resources, and current processes are probably only 10% efficient at converting them into usable product."

Evans leads the EPSRC Centre for Innovative Manufacturing, which connects systems engineers and business analysts at Cambridge's Centre for Industrial Sustainability with researchers at Cranfield University, Imperial College and Loughborough University. The Centre is funded with £5.7 million from the Engineering and Physical Sciences Research Council.

Centre researchers work with multinational businesses such as Toyota, Unilever and M&S to develop the knowledge and tools that will help manufacturers navigate their way through the complexities of designing sustainable industrial processes in the long term.

10%

current factory efficiency

"To live well, experts think that we must be able to manufacture what we need using less than a quarter of the current bio-capacity. What this means is a reduction of 75–90% in how much carbon-based energy and resources our industrial systems currently use," said Evans. "And to achieve this will mean a complete reshaping of how we manufacture."

His vision extends all the way to a future in which factories could have a net positive effect on the environment: "Part of the work we are doing on configurations would suggest that by the 2050s the air and water leaving factories might be cleaner than what's going in. A greater number will either use local materials or grow the materials they use – perhaps as nanostructures or using green chemistry. This will fundamentally change scale and location decisions for factories to the point where they will be so advantageous that people will want them at the end of their street."

Developing ideas of how eco-factories could look in the future is one aspect of the research carried out by the Centre. However, these are long-term visions, and the researchers recognise not only the complexities of change but also that the "window of opportunity for action is rapidly closing." One key focus of their research agenda, therefore, is to understand how industries can improve their efficiency and environmental performance now, without changing current products and processes.

75–90%

reduction needed in carbon-based energy use

"How can you find out how efficient a factory can be? You just ask common sense questions," said Evans. "We go into the factories to collect examples of sustainable industrial activity, identify new courses of action, and then publish these as case study reports." A database of over 1,000 effective practices in industrial sustainability has been compiled and will be generally available later this year.

For Toyota, for example, the researchers discovered that significantly better industrial performance is possible through innovative thinking and careful planning without relying on the development of a 'step change'.

Toyota operate nine manufacturing sites in Europe ranging from engine manufacture through to vehicle assembly. "Toyota took the route of developing action plans with challenging targets to reduce environmental impact – recycling waste water, sending zero waste to landfill and so on – and focused on individual aspects of manufacturing to develop best practice. By adopting these principles, they reduced the energy needed to make cars across their European factories by 44% in five years."

"Some factories are noticeably more efficient than others," Evans added. "We want to know why, and whether they are squeezing every last drop from best practice. If not, how much further can they go and what can competitor factories learn from this?"

Other companies studied by the team have focused their steps on improving environmental performance on packaging reduction (Philips), shifting operations from a product-based system to one in which it provides a service (Xerox), and building a new energy-efficient production facility (Adnams brewery).

"Understanding how far you can push current systems is the most urgently needed step. But technological development is also essential to achieve the significant changes in efficiency that we need," said Evans. To help this agenda, the Centre is also looking at the technology needed to manage factories. One software tool they have built – THERM (for THrough-life Energy and Resource Modelling) – models the way that energy, materials and water can flow around factories. "Traditionally, these processes are considered as secondary to modelling production of the product and yet they are integral to approaching sustainability at a factory level."

The THERM project, funded by the Technology Strategy Board, gathered a team of practitioners (Toyota and Airbus), academics (Cranfield University and De Montfort University) and software developers (Integrated Environmental Solutions) to create the software tool, now available to industry. The tool integrates the modelling of manufacturing processes within their environment – the factory building – to identify system-wide opportunities to reduce resource consumption, carbon emissions and waste generated.

"The greatest opportunity to reduce the environmental impact of an industrial system comes about when we consider the system as a whole, because the optimisation of any one part is ultimately constrained by other aspects," explained Evans, who is a member of the Foresight lead expert group that is combining the latest scientific evidence with futures analysis to help policy makers consider the Future of Manufacturing for the Government Office for Science.

44%

less energy now used by Toyota factories

Evans and his team believe that this 'systems thinking' approach is crucial. "The evidence we have seen from case studies shows that sub-system approaches can dramatically improve sustainability. But to help future generations meet the needs of humanity within the carrying capacity of the planet it will be important to develop the know-how to enable changes across the whole industrial system. Such a system is likely to look very different to today's global industry. We believe that manufacturing will change its shape."

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Time for Plan Bee

Insect pollinators provide a service worth an estimated £430 million to food, farming and retail sectors in the UK. How can we protect them, and enhance the sustainability of the UK food production system?

By carrying pollen from one plant to another, bees and other insects contribute to plant reproduction in almost 90% of our wild plants, and around 30% of our crops depend on them. But, as zoologist Dr Lynn Dicks explained, their future is under threat: "There has been a massive decline in some groups of insect pollinators. The number of bumblebee species in the UK dropped by around 30% between the 1950s and 1980s, and numbers of many large moth species in the UK have halved since the late 1960s."

Most scientists agree that pollinator declines are caused by the interaction of various factors including habitat change, the consequent loss of flowers and nest sites, agricultural chemicals, disease and possibly climate change.

"There's also an increasing acknowledgement of the important role pollinators play in food production," added Dicks. "Some fruit crops are completely dependent on pollinators, and for others pollination results in better quality fruit."

Dicks holds a Natural Environment Research Council (NERC) three-year Knowledge Exchange Fellowship. Her work on pollinator conservation has brought together key players to identify knowledge gaps and to devise collaborative projects to address them. Twenty large businesses, including Waitrose and Heineken, joined forces with representatives from government agencies, nature conservation agencies including Natural England and Buglife, and scientists.

Framed in terms of a business interest, pollinator conservation has moved rapidly up the political and business agendas. A consortium of UK research funders has recently invested £10 million under the Insect Pollinators Initiative to identify and mitigate the main threats. "All the food companies with a dependence on fruit production are thinking about these sustainability issues now," said Dicks. "Heineken, which makes Bulmers cider, uses about 30% of the UK apple crop, and apple yields are between 40% and 90% lower without pollinators, depending on the variety. Around 90% of the UK blackcurrant crop goes into Ribena, and without pollination blackcurrant yields drop by 10–40%."

"We looked at the knowledge available from academia, the private sector and government," said Dicks. Breaking down the issue into the status of pollinators, threats, and what could be done about these, the first round of discussions generated 246 'big' questions. From this, a set of 35 priorities were chosen for investigation.

> "Bringing scientists together with the business community at the start of the process is a radically different way of working"

"The highest priority was to understand the basic underlying ecology of the insects – how important the diversity of pollinators is to delivering a reliable pollination service," she added. Other priorities were to understand the relative contributions of wild and managed pollinators to crop yield, and the sub-lethal effects of chemicals on wild pollinators. The next stage of the project is to address some of the top 15 knowledge needs through new research.

The work formed the pilot for a wider NERC-funded Knowledge Exchange Programme on Sustainable Food Production by the Universities of Cambridge, Bangor, Lancaster, Leeds and Reading and the Plymouth Marine Laboratory. Aiming to enhance the use of science in making UK food production systems more environmentally sustainable, the Programme has developed a web-based database of scientific evidence (www.nercsustainablefood.com), so that all sectors with an interest in sustainable food production can access knowledge.

"In many cases, the scientists in our project already knew about the issues and had the solutions, but the people who needed to know weren't aware of this knowledge," said Dicks. The priority knowledge needs identified by this work will structure ongoing efforts to make science accessible to practitioners, and will help to guide future science policy and funding.

"Bringing scientists together with the business community at the start of the process is a radically different way of working," said Dicks' collaborator Bill Sutherland, Miriam Rothschild Professor of Conservation Biology in the Department of Zoology. "This approach could apply to almost any academic field. We want to fundamentally change the way that conservation policy and practice works. This project is about pollinators, but if the knowledge exchange process works, we can start looking at the bigger picture."

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Amazonia at a Crossroads

The Amazon rainforest faces an uncertain future – one that an international research network hopes to help steer towards sustainability.

The numbers associated with the Amazon are truly staggering. It encompasses nine countries; contains at least a tenth of the known species in the world; provides a home and resources to 31 million people; stores the equivalent amount of carbon to a decade of human-induced emissions for the entire planet; and discharges a fifth of the world's fresh water.

However, rapid social and ecological change, borne on the back of deforestation, harvesting of natural resources and a changing climate, has left the future of the world's largest remaining tropical forest uncertain – Amazonia, today, is "standing at a crossroads", as Dr Toby Gardner describes.

He points to the existence of tough trade-offs that underpin the region's challenges: "The demand for land and natural resources is driven by the development needs of one of the world's largest emerging economies, as well as by the insatiable global food and commodities market. Understanding what management practices can best achieve both economic development and environmental conservation is central to addressing this challenge and shepherding the creation of a more sustainable Amazon."

Gardner leads a new research programme that is motivated by helping to solve this dilemma – the Sustainable Amazon Network – alongside colleagues at Lancaster University, the Goeldi Museum in Belém (Brazil) and the Brazilian Agricultural Research Corporation (Embrapa), with funding from the Brazilian and UK governments and The Nature Conservancy, among others.

The Network's 100-strong group of researchers and students from over 30 institutions are working with conservation organisations, farmers and government officials. Their approach is to assemble an evidence base on the sustainability challenges and ecological consequences associated with land uses and management strategies, and to use this to test the effectiveness and risks of alternative policy choices facing local people and regional governments.

At the heart of the research is an appreciation of the complex array of interactions and feedbacks that characterise the changing face of Amazonia. The project takes as its 'laboratory' two regions of the eastern Amazon: Paragominas, a region infamous for lawlessness, violence, land grabbing, illegal sawmills and rampant forest clearance until the 1990s; and Santarém-Belterra, once a centre of pre-Colombian civilisation, with a long history of farming and now home to smallholder farms and larger agricultural enterprises.

What makes the project distinct from many other research initiatives is the collection of matched data from the same network of landholdings on changes in both the ecological and the socio-economic characteristics of different land and forest use systems. The team's survey design has enabled information to be collected across the full wealth spectrum, from the poorest to the richest farmers, while allowing comparisons at multiple spatial scales – between different farms, catchments and regions.

The result is one of the most comprehensive field assessments ever undertaken in the tropics. Critical issues that are being addressed include the identification of potential threshold effects of deforestation on the degradation of ecological systems, and the identification of strategies at both farm and municipality scales that can effectively reconcile conservation and development goals.

"In addition, one of the longer term implications of any initiative like this is the fact that a large group of students and researchers, many of whom are Brazilian, have been exposed to new ideas and new ways of thinking about sustainability problems, and this, perhaps above anything else, will be the most valuable legacy of our project," added Gardner.

Can the world's largest tropical forest biome be transformed into a sustainable ecological system? "There is a short window of opportunity and there is potential for recovery," said Gardner. "But we cannot afford to be complacent."

Toby Gardner's discussion of how science can make more-effective contributions to policy available online.

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9 countries

10% of the world's known species

Home to 31 million people

Discharges 20% of the world's fresh water

Stores 10 years' equivalent of carbon emissions

Testing the Water

A new online tool enables users to assess not only how much water we use and for what, but also how we can mitigate against future scarcity.

Water, like many other natural resources, is in both high demand and limited supply. In any one region, this precious substance is needed to sustain the domestic requirements of the population, irrigate crops, maintain ecosystems and assist in manufacturing and energy production.

Focusing on the state of California, a multidisciplinary group of Cambridge researchers has developed a model to calculate monthly and annual water demand. Moreover, because the model calculates future scenarios, it provides a means of assessing what can be done to mitigate against water scarcity.

Dr Julian Allwood, who leads the Foreseer Project that created the tool, explained: "We're aiming to create visually compelling messages about resource use now, and in the future, to help users understand the consequences of their choices. We want to help identify opportunities where efficiencies or demand reduction would be effective, and equally we need to demonstrate which actions would have only a little impact."

For resource managers, policy makers and industry, understanding how to sustainably manage the competing demands on a limited resource is a considerable challenge. An estimated 1.2 billion people currently experience water scarcity and, as the population rises, demand will increasingly outstrip supply.

At the heart of the online tool is the Sankey diagram: a visualisation technique

Image
Example of a Sankey diagram

"It reveals the scale and impact of human choices and directs attention towards actions that might make a real difference"

that transforms the plethora of data into an intuitive representation. Horizontal lines trace the flow of water from its various sources (rainfall, surface water, ground water, recycled water), through the services that use it (agriculture, industry, domestic and the environment), to where it ends up, with the relative width of each line representing the amount of resource at each stage.

The model is among a suite of similar tools being created by the BP-funded Foreseer Project. The first is focused on energy, land and water use in California, and is now being used by members of industry, academia and NGOs. Recently, the researchers began work to implement and visualise energy scenarios being considered by California energy planners to investigate the land and water resource implications of future energy use.

"There is a certain attraction in being able to see all demands on a resource being traced through to its end point," explained team member Dr Jonathan Cullen. "It reveals the scale and impact of human choices and directs attention towards actions that might make a real difference. Because the tool is dynamic, it's possible to 'toggle' multiple water management policies to see what the outcome on energy, land and water resources might be."

In California, the water resource issues already faced by the state are likely to worsen with the predicted climate-related reduction in snowpack in the Sierra Nevada. At the same time the demand for water for agriculture, urban uses and the environment could also increase, which may lead to intense competition between these different sectors.

It's a gloomy picture but, as researcher Dr Liz Curmi described, the aim of the tool is to look for positives. "We built the tool to be user centred because we wanted people to think about the positive actions they can take to reduce stress on the resource. So, a policy maker might ask whether increasing desalination would make a difference, and the answer, on a state-wide level, is no. But reducing the amount of irrigated water used by the agricultural sector through growing less water-intensive crops could have a dramatic effect."

Key to the Foreseer Project is the ability to look at the whole picture, to create models that go beyond focusing on a single resource to integrate water, energy and land use. It's a strategy intended to understand what Professor John Beddington, former Chief Scientific Advisor to the UK government, termed a "perfect storm" of insufficient energy, water and food.

"This cohesive view differentiates us from other modelling research groups," said researcher Grant Kopec. "By integrating these resources, we think we can identify trade-offs between sectors that you might not normally think of as being connected, for instance between power production and agriculture."

The team, which also includes Bojana Bajželj and Ying Qin, works in the Department of Engineering but is supported by a multidisciplinary group of nine co-investigators from seven different departments. "The collaboration of experts from so many disciplines has been critical to the iterative process we go through to create our models," explained Allwood. "We all have an interest in the demand on global resources but this may be from a geographical, atmospheric, biological, engineering, mathematical or management perspective – all are needed if we want to design mitigation plans that add up."

Now the team is extending its focus to other regions of the world including China and the UK with, respectively, funding from BP and as part of a multi-university consortium (WholeSEM) funded by the Engineering and Physical Sciences Research Council.

Eventually, the aim is to connect regions, countries and continents to arrive at a set of linked global assessments of water, land and energy resources. Already, they have accomplished this for global man-made greenhouse gas emissions: connecting services such as food and transport via the business that delivers them through to the fuel each uses and the emissions that are created.

"By visualising the data as Sankey diagrams, we find out that the scale of intervention really matters," said Allwood. "One of the big things we've learned is how increasing efficiency is not enough – we also have to reduce demand because this can have far more widespread positive impacts than previously considered."

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What impact will new technology have on tackling emissions?

Models such as those being developed by the Foreseer Project provide unparalleled insight into current and future demand for resources, and their impact on greenhouse gas emissions. What if we could also take into account the fast pace at which new technologies are evolving? This is the aim of a new project in the Cambridge Centre for Climate Change Mitigation Research (4CMR).

Dr Jean-Francois Mercure, who leads the research, asserts that building this factor into models will help understanding of the degree to which improvements in energy-consuming technologies can help the government reduce emissions, which in turn might help their development: "Technology comes to life through timely investments and policy incentives, and so it's important to include technology diffusion and its pace in energy modelling.

"Most models... disregard the process by which new technology regimes come into existence"

"However, this is challenging and most models today attempt to calculate cost-optimal technology roadmaps based on current technology, which is not necessarily likely to happen, and which disregard the process by which new technology regimes come into existence."

Technological change occurs constantly, either following advances in industrial systems or through evolutions of behaviours, such as the move towards electric cars. With funding from the Engineering and Physical Sciences Research Council, Mercure has begun work on a computational modelling system that takes into account the profile of technology transitions in the past to project how new transitions could arise in the future.

The research is being carried out at 4CMR in the Department of Land Economy in collaboration with the Tyndall Centre at the University of East Anglia, the UK Department for Energy and Climate Change, the UK Energy Research Centre and Cambridge Econometrics.

Feature article available online

Image
Hildegard Diemberger with shepherds in the Himalaya

Credit: Dr Hildegard Diemberger

“The honour of the snow-mountains is the snow…”

For those who live in the shadow of the world’s highest mountain range, the snow-capped peaks have long been an indicator of the ‘health’ of their community. Now researchers are raising awareness of the value of local knowledge as a proxy for gauging environmental change.

The everyday lives of the Porong people of southwestern Tibet are shaped by their mountain landscape. The condition of the snow-capped peaks is just as central to their age-old narratives and rituals as they are to their contemporary agricultural practices. The Tibetans consider that the ‘ancient spirits’ of these places control the weather, wildlife, fertility, resources and all that determines the wellbeing of the community; according to their songs, ‘The honour of the snow-mountains is the snow… may there not be any change, may prosperity prevail.’

Over the course of two decades of living and working in the region, social anthropologist Dr Hildegard Diemberger has frequently encountered the connection between the Tibetans and their Himalayan landscape.

“I noticed that as much as people were transforming the landscape in which they were making a living, the landscape – and the increasingly unpredictable weather, drying up of springs and receding snowline – was changing the lives of the people who were experiencing it. Anticipating nature has been essential to being able to adapt to its seasonal transformations, as well as to detect longer-term abnormalities.”

Increasingly, researchers like Diemberger are raising awareness of the value of such local knowledge of the natural environment as a proxy for gauging environmental change, and as a step towards understanding the role of humans in causing that change. Recently, she contributed to a research network led by Dr David Sneath and Dr Barbara Bodenhorn (both in the Department of Archaeology and Anthropology) that examined the significance of natural proxies – ranging from the snow and ice of the Arctic to the songbirds of the Tibetan plateau and the ‘bog oaks’ of the East Anglian Fenlands – in communicating cultural knowledge of environmental change.

“Climate change is a human issue and to understand it requires far more than climate science. We hope that these cross-disciplinary exchanges will produce further conversations and new approaches to action,” said Sneath.

One such approach has been the teaming up of Diemberger with meteorologist Professor Hans Graf, from the Department of Geography. Graf has been modelling the Tibetan microclimate through glaciers, meteorological phenomena and vegetation. Diemberger explained: “In a world in which the conceptual models that inform decision makers are increasingly determined by scientific investigation, politics and economics, we asked is there a space for the ancient local spirits and the Buddhist ideas enshrined in Himalayan landscape to provide insight into issues of environmental change?”

The pair discovered a remarkable degree of common ground. Graf’s scientific model showed that the clouds are significantly affected by dew, which in turn is determined by the landscape’s vegetation cover and is thus vulnerable to local land-use change, especially overgrazing.

Meanwhile, Diemberger has found that the impact of grazing animals on the pastureland is determined by the movement of herds and herders according to ancient rules – a migration that Sneath identified over a decade ago as decreasing as a result of resettlement strategies in the region, promoted in the name of a host of different reasons including environmental protection.

“These crossovers highlight the link between livelihood, landscape and weather,” said Diemberger. “We have discovered the usefulness – and the limits – of climate models and what can be gained from the records and observations of people who have been living in this environment for centuries.

“Deteriorating local features such as the loss of permanent snow fields are often at the centre of a blame game between local rural communities and state administrations on whether local practices or industrial development are responsible for what people are experiencing. Our belief is that by looking at natural phenomena in their social and cultural context, scientific investigations can discover and harness a host of unusual ‘proxies’ – mountains and lakes, ice and snow, clouds and dew, birds and grasses – to address the hugely complex issue of sustaining the environment in a changing climate.”

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On Yer Bike!

With governments around the world under increasing pressure to reduce their greenhouse gas emissions, transport systems are under scrutiny. Dr James Woodcock has introduced another factor into the equation: population health.

Motorised transport is the fastest-rising cause of energy-related greenhouse gas emissions and there’s a strong imperative to address this by moving towards a low-carbon transport system. Moreover, as Woodcock, from the Centre for Diet and Activity Research, explained: “It’s possible to benefit public health at the same time.”

But which approaches to achieving a low-carbon transport system would provide the biggest health benefits?

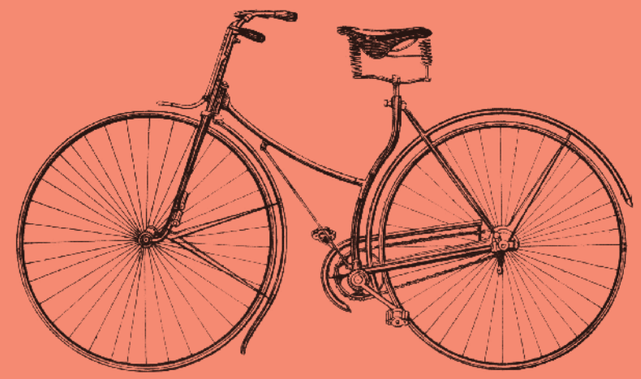
“We can think about the problem in two ways,” he said. “We can evaluate the impacts of an intervention such as new cycling infrastructure, or we can develop scenarios around what a healthy, low-carbon future transport system would look like, and then we think about how to achieve major changes in how people travel. We often see quite small effects from the interventions happening now, whereas potentially large things are possible.”

“Cycling could have a big role to play,” he said. “But to achieve this you’d have to start thinking about changes in land use to reduce trip distances, and cultural and infrastructural changes to make cycling an everyday mass activity for short- and medium-length trips.”

Woodcock has led the development of an Integrated Transport and Health Impact Modelling (ITHIM) tool, which models the health impacts of travel behaviours on both population health and greenhouse gas emissions.

“We’re seeing different effects in different populations,” said Woodcock. “In health terms, switching from driving to cycling consistently shows a net benefit, and the greatest benefit comes from getting older people more active. However, a complicated web of other problems arises. In some contexts, such as inner London, cyclists seem to face notably higher injury risk than users of other travel modes,” he said. “They also breathe harder so are inhaling more air pollution, which is bad for health.

“Health benefits link transport and environment problems, and we need to be sure of the best route to achieving the biggest benefits”



But on the other hand, they are not in a car putting other road users at injury risk or producing pollution for everyone else. We need this model to tell us which is the more important effect.”

There are also rebound effects to consider. “If I sell my car and buy a bike, I’ll have money left over, and where do I then spend that money?” he asked. “I may end up causing greenhouse gas emissions somewhere else, and it’s complicated to account for these second-order factors.”

ITHIM has now been taken up in California to evaluate transport plans in the San Francisco Bay area. It showed that a shift from driving to walking and cycling on short trips reduced the burden of cardiovascular disease and diabetes by 14% and reduced emissions by around 14%. By contrast, low-carbon driving reduced emissions by 33.5% but cardiorespiratory disease burden by less than 1%.

The results are feeding into new policy in which a combination of active transport and low-carbon driving could meet legislative emissions mandates. Meanwhile, working with the Greater London Authority, Woodcock is also evaluating the impact of achieving the Mayor’s cycling targets and has also separately modelled the impacts of the Barclay’s Cycle Hire Scheme.

With funding from the Economic and Social Research Council and the Medical Research Council, Woodcock is leading two additional projects to address the problem of how to achieve the necessary behaviour change. By focusing on the development of cycling cultures through social learning and social influence, and by understanding the unintended outcomes that policies might bring about, these projects are attempting a different approach from those used in traditional transport modelling.

“Our research brings out a potential good news story,” he added. “Health benefits link transport and environment problems, and we need to be sure of the best route to achieving the biggest benefits.”

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"There is everything still to discover, and most of it will turn out to be, for unexpected reasons, remarkably useful"

Inspired by Nature

Researchers are unravelling nature's secrets to develop new energy-generating technologies for a more sustainable future.

Through billions of years of evolution, life on Earth has found intricate solutions to many of the challenges scientists are currently grappling with. Now, taking a leaf out of nature's book, two research projects are examining the early stages of photosynthesis – the process by which plants and some bacteria capture the sun's light energy and convert it into chemical energy – to aid development of more-efficient solar panels and transport fuel.

I Image
The light-harvesting complex in green sulphur bacteria

From quantum mechanics to solar panels

Physicists Dr Alex Chin and Dr Nicholas Hine at the Cavendish Laboratory's Winton Programme for the Physics of Sustainability are focusing on the ancient green sulphur bacteria and their astonishing efficiency at converting light energy into chemical energy to provide new understanding of renewable solar energy.

Green sulphur bacteria are found in places with very little light, and have developed clever solutions for capturing and converting light energy.

"The light-harvesting states of photosynthesis happen extremely fast – within a nanosecond, if not picoseconds," said Chin. "We're interested in that efficiency and how it's managed. Biology has evolved phenomenally subtle systems to funnel light energy around and channel it to the right places. It has also become incredibly good at building tiny devices that work with high efficiency, and at replicating them millions of times."

"Light harvesting is one area where evolution has produced systems that take advantage of quantum mechanics," said Hine. "We want to make devices that harvest the maximum amount of the available sunlight. Existing materials, like the solar cells on roofs, only absorb about 20% of energy from the sun to turn into electricity. The trick is to make sure the material is tailored to absorb all the energy it possibly can. This way, solar panels will become an increasingly attractive source of sustainable energy in the future."

"We need to know about the molecular arrangements to identify the properties that lead to this high efficiency," added Chin. "I use Nick's simulations as input into a model I can set in motion to see how energy will flow." By working together, the pair are developing an understanding of this photosynthetic system, from where each individual atom is positioned to how the whole system functions.

The idea is to generate broader design principles for new nanomaterials that can be used to build better types of photovoltaic devices. "Once we understand the system, we can then move into synthetic chemistry, solid-state physics and materials science, and see if we can mimic it," said Chin. "This may be in a simpler way, but hopefully a scalable one that is useful for industry."

Chin and Hine's work is representative of the ambitious aims of the Winton Programme. "The Physics of Sustainability defines a grand challenge," said Professor Sir Richard Friend, Director of the Programme. "Sustainability is about finding better solutions in areas where we use huge amounts of material, like lighting, batteries and water-purification systems. These are areas where current solutions are inefficient and we should be able to do much better.

"There is everything still to discover, and most of it will turn out to be, for unexpected reasons, remarkably useful."

Air, water and sun: 'green gasoline'

Meanwhile, in the Christian Doppler Laboratory in the Department of Chemistry, Dr Erwin Reisner and colleagues are creating artificial photosynthetic systems that will turn air and water into transport fuel. His hope is that homeowners will one day have their own power plants that use sunshine not only to power their homes but also to synthesise petrol for their cars.

"Given that almost 80% of the world's energy is used in the form of fuels, one of the main challenges is to create a carbon-neutral, sustainable alternative that is cost-effective enough to replace the usage of petrol and diesel," said Reisner.

The technology he is developing uses solar energy to separate the elements that make up water and carbon dioxide (CO_2). The reaction creates synthetic gas, or syngas – comprising the energy-rich hydrogen (H_2, which can itself be used as a fuel) and carbon monoxide (CO). This mixture of gases can be converted into liquid hydrocarbons such as petroleum through an established industrial process.

"Syngas has been made successfully at an industrial level for decades by the petrochemical industry for the production of pharmaceuticals, plastics and fertilisers," explained Reisner, whose research is funded by the Engineering and Physical Sciences Research Council, the Christian Doppler Research Association and the OMV Group. "But it requires fossil fuels to make syngas, thereby depleting our natural reserves and producing the greenhouse gas CO_2 as a by-product. The process we are developing is sustainable because it takes carbon from the atmosphere only to return it when the syngas is used for the release of energy."

Reisner's team has created a synthetic small molecule that mimics the activity of biological catalysts called hydrogenases, which are found in microbial organisms and produce H_2 from water. Whereas efficient H_2 generation requires the catalyst platinum, which is expensive and in relatively short supply, the artificial catalyst uses the abundant metals iron, nickel and cobalt.

A first milestone was reached last year when the scientists demonstrated that it is possible to generate H_2 in a test tube on the bench, in air, by mixing the synthetic catalyst with a dye that absorbs light and water.

Now a further milestone has been reached. "In nature, hydrogenases take up electrons from their environment," he said. "We wanted to find a way of providing these electrons to our synthetic catalyst in a sunlight-driven reaction and we turned again to biological systems for clues. Without the electrons, the hydrogenase or synthetic alternative can't work."

Photosystem II (PSII) is a plant protein that captures photons of light and uses them to energise electrons and oxidise water to produce O_2. The researchers have now integrated this protein in a synthetic system to extract electrons to produce H_2. By combining the synthetic version of PSII and a synthetic hydrogenase, the former captures light energy and feeds electrons to the latter.

But can the technology make the transition from test tube to the gigatonnes required for industrial scale-up? "We have to be realistic and a series of breakthroughs is still required to make our scenario a reality. Even if we have these tomorrow, it will take at least 20 years before we see this type of technology providing the majority of the world's transport fuel," cautioned Reisner. "That said, we are confident that renewable syngas, a 'green gasoline' technology, will be able to drive our current industry in a sustainable way."

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Maxwell Centre to bring together frontier research and the needs of industry

A new centre at the Cavendish Laboratory dedicated to solving global challenges such as natural resource demand will be created with £63 million funding from government and business.

Building on the innovative activity of the Winton Programme for the Physics of Sustainability, the newly funded Maxwell Centre will cover many aspects of fundamental physics research that are relevant to areas such as renewable energy.

Scientists from industry will work alongside Cambridge research groups, engendering a two-way flow of ideas and exposing the best early career researchers to scientific problem-solving that relates directly to industrial need.

"A major effort to go beyond the boundaries of traditional physical science concepts"

Professor Sir Richard Friend, who will be the first Director of the Centre, explained the significance of the development: "The Maxwell Centre will be the vehicle for translating 'blue skies' research into products of importance for the industrial sector. This will not be conventional research or 'business as usual', but a major effort to go beyond the boundaries of traditional physical science concepts. We will combine work on the specific challenges facing collaborators with research into areas at the edges of current conception – the 'unknown unknowns'."

Funding for the new building, which is due to open in 2015, was raised through philanthropic gifts, industrial contracts and the Higher Education Funding Council for England.

www.winton.phy.cam.ac.uk

Credit: Jacqueline Garget

Inside out

Meeting Professor Sarah Franklin

Investigating a reproductive technology at its birthplace, Sarah Franklin talks about her enduring fascination with the medical intervention that has re-written the rules of nature, and about her love of chainsaws and cycling.

The technique of in vitro fertilisation (IVF) was devised in Cambridge by the late Professor Robert Edwards, who in 2010 won a Nobel Prize for what has been described as "a milestone of modern medicine." Since its successful introduction in 1978, IVF has moved from being a highly controversial clinical application to a routine procedure that has enabled over five million babies to be born to couples with fertility problems.

Professor Sarah Franklin, who was elected to the University Professorship in Sociology in 2011, has followed the technology's rapid development with fascination since the early 1980s: "The remarkable success of IVF is a unique model for future biomedical innovation. How did a new technology become completely normal? Why is IVF so popular, given that it still fails more than it succeeds? This is an intervention that has changed the meaning of fertility, the meaning of reproduction and the meaning of technology."

Now, with funding from the Wellcome Trust, the British Academy and the Economic and Social Research Council, Franklin has assembled a research team to study the history and sociology of IVF in the UK. As a world-leading expert on the social aspects of reproductive and genetic technologies, she works closely with clinicians, patients, scientists and policy makers to widen their sociological engagement with emerging issues in bioscience.

Q What's the point of your research?

A I'm interested in what it means for human reproduction to have become a technological process, and how biology is being changed by technology. I study assisted conception by IVF, a hugely successful translational technology. IVF has evolved rapidly and is now a major global industry, as well as a key technology for basic science. It offers a unique case study in how we understand both technological and biological change as social and historical processes.

Q Where do you have your best ideas?

A On my bicycle. I bought a 1939 Raleigh Roadster for £15 in Brighton when I first came to England as a graduate student, and I ride it everywhere.

Q Ever had a Eureka moment?

A That's the greatest thing about being an academic – you get to have them all the time. In the 1980s, I realised that reproductive technology would significantly change not only reproduction itself, but also how we think about what it means to be biological. More recently, I've realised that the human embryo is now a technology itself, and that IVF has changed our understanding of kinship and parenthood, as well as biological relatedness. It had normalised synthetic biology before this term was even in widespread use.

Q What might others be surprised to learn about you?

A I have three chainsaws and I used to compete as a lumberjack. When I was a teenager I could split a match and light it with an axe. I grew up in New England, where people can talk forever about wood: what type they have, how they collect it, how they stack it. Cutting wood is my favourite hobby; it's great exercise and I find it the most therapeutic thing in the world.

Q What's the best piece of advice you've ever been given?

A Never be afraid of being underestimated. Funnily enough this is motivational in lots of situations, like when you're starting a new job. Being overestimated can crush you and be quite damaging, but being underestimated can boost your confidence because it means you're always over-performing.

Q If you could wake up tomorrow with a new skill, what would it be?

A I'd love to be able to programme my own computer. There are so many little things that computers do automatically that are really annoying, and not being able to change them is so frustrating.

Q How would you describe your childhood self?

A Curious, easily entertained, independent.

Q What is your favourite research tool?

A Conversation. It's the best tool for collectivising human thought, which is always the best way to think better. Cambridge is a great place for conversations; there are so many opportunities to talk to people who are really excited about something you've never heard of before.

Q Who or what inspires you?

A People who are able to create an empowering working environment for others.

Q How do you relax?

A Making fires and riding my bike.

Q How would you like to be remembered?

A As someone who was never dull.

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Cover
Hildegard Diemberger with shepherds in the Himalaya. Researchers like Diemberger are raising awareness of the value of local knowledge as a proxy for gauging environmental change. Find out more on p. 30.

Credit: Dr Hildegard Diemberger