

Research

Horizons

Pioneering research from the University of Cambridge

Issue 30

Spotlight

Future of cities

Feature

**Rejuvenating organs
for transplant**

Feature

**Linguistic time
travelling**



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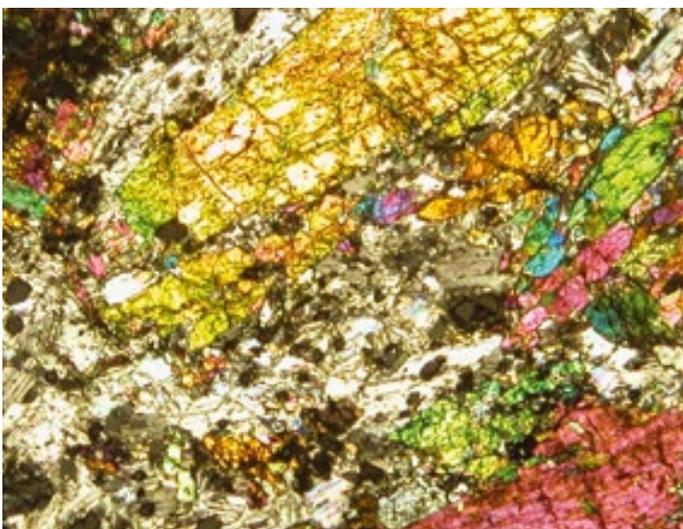
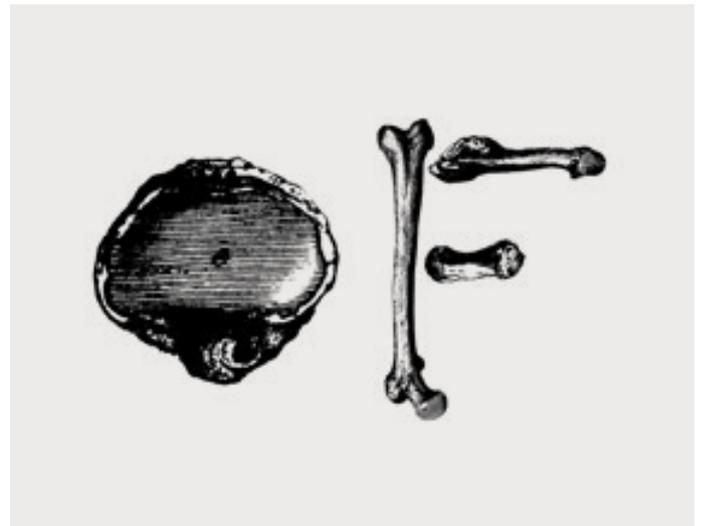
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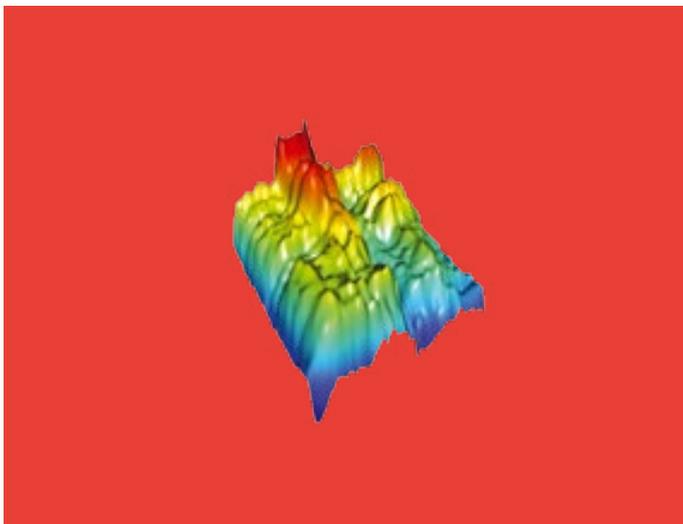
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Welcome

Welcome to the 30th issue of *Research Horizons*, in which we focus on the future of cities, a topic of increasing interest across the University.

Today, over half the world's population lives in urban areas; in 30 years, it will likely be three quarters. That's why thinking about the future of our cities really matters.

Of course, each city faces its own unique future of pressures and opportunities. But there are common issues. The past few years have seen an increasing focus by policymakers, academia and business on what can be done not just to mitigate challenges but also to make cities thrive and work well.

Our health and wellbeing, the economy and the environment, social cohesion and security, the longevity of our infrastructure: all are facets of the future of cities that require proactive and innovative solutions. These are the areas we have focused on in this issue.

Finding ways of maximising urban sustainability holds particular resonance for early-career researcher Patrick O'Hare. In his Extreme Sleepover article, he describes the work of families who recycle valuable materials discarded in Uruguay's largest landfill. With predictions that the total volume of global waste generated will double in 10 years, thinking about waste as a recoverable resource is becoming an increasing priority.

Other articles in this issue describe a new method that is increasing the number of transplantable organs, how the American home is depicted in film, the experiences of EU migrants working in the UK, the 'shape' of language sounds, and the search for rare earth elements from the air. All this and a project that follows the moves of a cuckoo named 'Disco Tony'. A reflection of our diversity in research!

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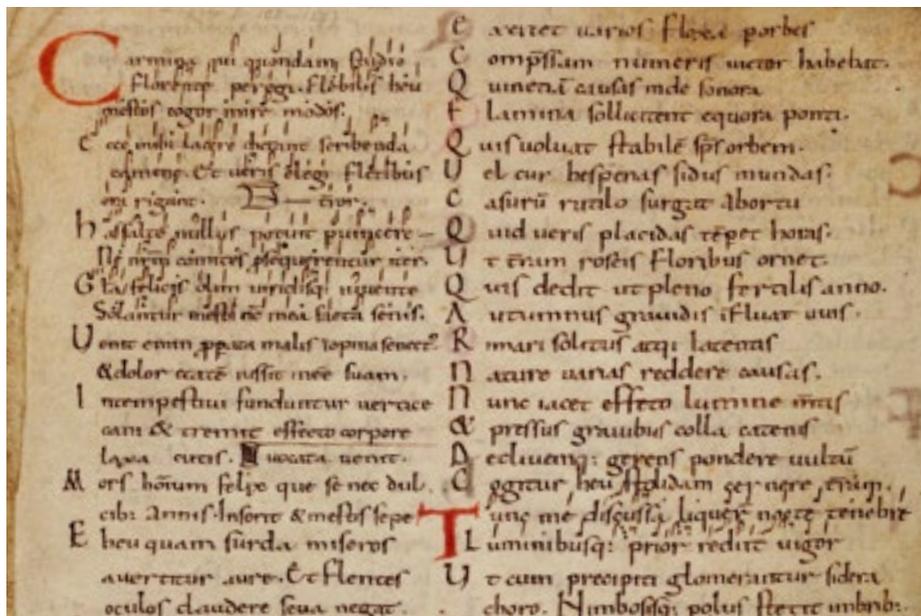
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News



Credit: Cambridge University Library

First performance in 1,000 years

'Lost' songs from the Middle Ages have been brought back to life after being 'reconstructed' by a Cambridge researcher.

The 11th-century manuscript leaf was removed from a collection called the *Cambridge Songs* by a light-fingered visiting scholar in the 1840s and only rediscovered by accident 142 years later in Germany. It features music set to poetry written by Roman philosopher Boethius during his 6th-century imprisonment, before his execution for treason.

But its rediscovery was only part of the story. The task of performing ancient works today is not as simple as reading and playing the music in front of you. A thousand years ago, music was written in a way that recorded melodic outlines called neumes, but not 'notes' as today's musicians would recognise.

It took part-detective, part-musical time traveller Dr Sam Barrett, from the Faculty of Music,



Image
Rediscovered leaf of the
Cambridge Songs

two decades of painstaking work to reconstruct the melodies, furthering understanding of how medieval music was composed and performed.

Barrett's scholarly groundwork involved gathering together surviving notations from the *Cambridge Songs* and other manuscripts around the world, and then applying them to the principles of musical setting during this era.

"The traces of lost song repertoires survive, but not the aural memory that once supported them," explains Barrett. "We know the contours of the melodies and many details about how they were sung, but not the precise pitches that made up the tunes."

"There have been times while I've been working on this that I have felt like I'm in the 11th century, when the music has been so close it was almost touchable."

Hear the music:
<http://bit.ly/1rwhHJS>



Maxwell Centre opens

New Centre brings together physics research and the needs of industry.

Funded by government and business, the £26 million Maxwell Centre will enable University researchers and industrial collaborators to work together to translate 'blue skies' research into products vital for industry.

The Centre is sited at the Cavendish Laboratory and will focus on research in areas such as efficient energy generation, storage and use, photovoltaics, refrigeration, lighting and ICT, as well as advanced scientific computing, materials science research, nanoscience and biophysics.

"New research opportunities are often revealed by industrial activity," explains Professor Sir Richard Friend, its new Director. "Their solutions require transfer of ideas and techniques often from fields well away from the industry."

"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'."

The Centre will also house two Engineering and Physical Sciences Research Council Centres for Doctoral Training and the SKF University Technology Centre.

News in brief

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

19.04.16

New research shows a 20% fall in new cases of dementia in the UK over two decades, mainly in men.

15.04.16

British steel could be saved, if the industry is willing to transform itself, claims a new report.

Green gold

A unique facility will test ways of turning algae into fuel and food.

Algae have long been considered as a potential biofuel to replace fossil fuels – they convert solar energy into chemical energy with high efficiency, they grow fast, and they live in water and so don't take up land that might be used for food crops. Even their by-products are useful as valuable sources of protein for fish and animal feed.

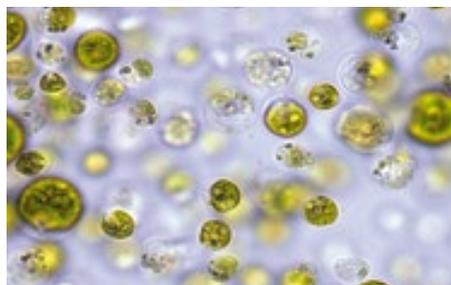
However, making the most of this 'green gold' needs many aspects to be optimised, in particular to avoid consuming more energy during algal production than is generated.

The aim of the newly opened Algal Innovation Centre (AIC) in Cambridge University's Botanic Garden is to facilitate new innovations in growing and harvesting algae at scale that are both economically feasible and environmentally sustainable.

Working with industrial partners, the AIC will also test whether algae can be used as a source of protein and nutraceuticals, for a variety of food and beauty products.

Professor Alison Smith, from the Department of Plant Sciences, explains: "It's a unique facility for the UK. The goal is to connect bench research through to market-place products."

The AIC is funded by the University and the European Union's INTERREG EnAlgae project, which aims to reduce reliance on fossil fuels in North West Europe by developing algal biofuel technologies.



Credit: Learning Together/Ministry of Justice

Inside information

The wealth of untapped academic talent inside the criminal justice system has been illuminated by a ground-breaking project.

An innovative project in which Cambridge students and prisoners studied together at a Category B prison in Buckinghamshire has broken down prejudices and created new possibilities for all of those who took part.

The Learning Together initiative was funded by the University's Teaching and Learning Innovation Fund and the British Academy and consists of carefully structured, 12-week courses involving graduates studying for the MPhil in Criminology at the University of Cambridge and students from the prison itself. All of the participants co-operate on equal terms, sharing exactly the same study materials, and working together in small group sessions.

Based on findings from the project, the organisers Dr Ruth Armstrong (Institute of Criminology) and Dr Amy Ludlow (Faculty of Law) argue that more should be done to develop inclusive, empowering and

socially transformative approaches to learning in both universities and prisons. They call for the development of an approach that is "more porous" in terms of its creative engagement with the outside world, one that considers prisoners as potential assets to society rather than people who merely require correction.

Gareth, one of the participants from HMP Grendon, has written a review of an academic book now published in a peer-reviewed journal. In his graduation speech, Gareth said: "For a large part of my sentence, who I am has been entirely synonymous with the reasons I ended up in prison. Reflecting on the initiative, it seems that the overwhelming product was that I was reminded of being someone other than the person who committed these offences.

"I am someone who has valid and useful opinions, I have an interest in how society works and the connectedness we feel with the other people who we share this world with. I am developing a sense that not only do I want to help people – I am starting to believe I can."

13.04.16

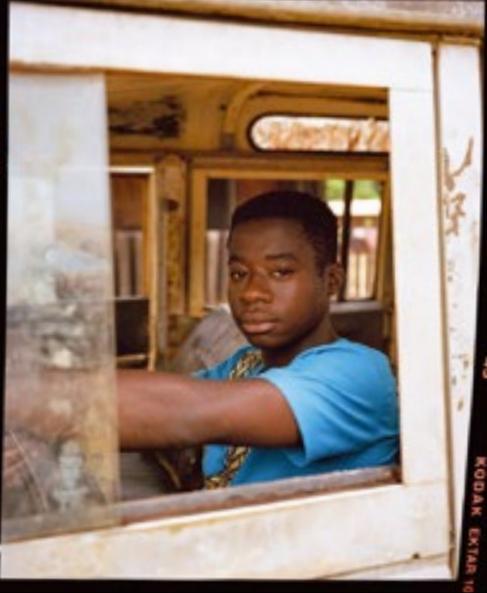
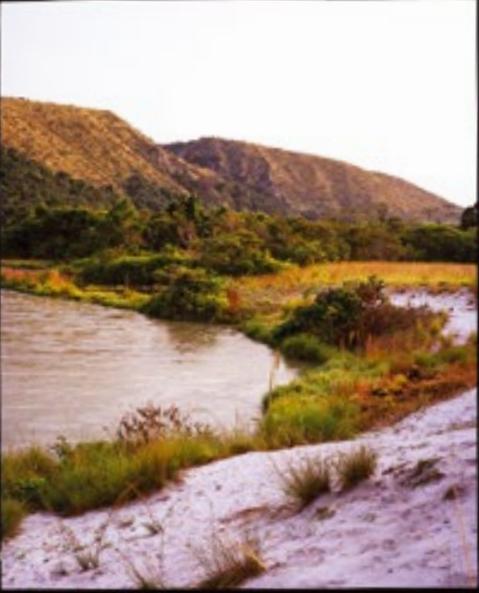
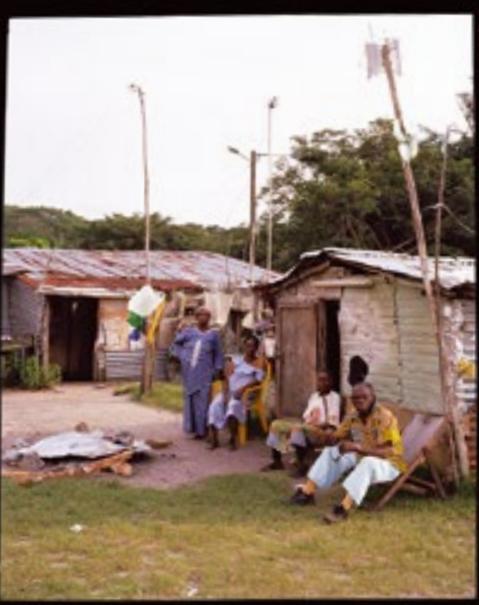
The first 'big data' investigation of graduate earnings reveals variations depending on background, degree and university.

06.04.16

Sir David Attenborough opens a new campus in Cambridge for the largest grouping of conservation organisations and researchers in the world.

22.03.16

Cambridge will lead a major new research project to study the benefits of multilingualism to individuals and society.



Earth, wind and flyer: the moves of Disco Tony and friends

1 July 2015: Disco Tony sighted in a Welsh bog.

27 July 2015: traced in France, Italy and Libya.

21 August 2015: south of the Sahara.

9 October 2015: in an unprecedented move, he veers west towards Chad, Nigeria and Cameroon.

13 January 2016: Gabon, west coast of Africa.

07 March 2016: now heading for Wales, he's got a long way to go.

Disco Tony has travelled over 5,000 miles. He is grey with a yellow ring around his eyes. He is a cuckoo, but not just any cuckoo. He is one of a very special group of birds whose every move is being monitored.

Earlier this year, Toby Smith followed the moves of Disco Tony and his fellow cuckoos – a journey that took him to the forests of Gabon in West Africa and the fringes of the Batéké Plateau grasslands.

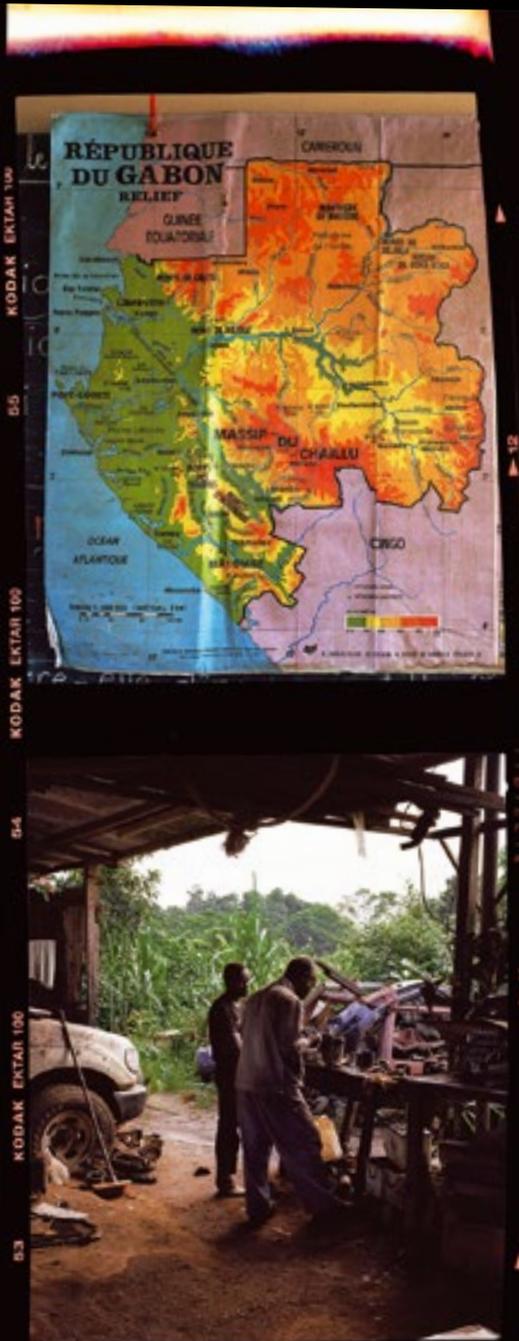
As a photojournalist – and first Leverhulme artist-in-residence at the University of Cambridge Conservation Research Institute (UCCRI) – his aim was both to photograph the landscape and to talk to the local villagers and hunters with whom the cuckoos share their home.

The result is a remarkable series of images that is providing bird researchers with a comprehensive idea of the rural landscapes in which the cuckoos overwinter.

The cuckoos all carry tiny lightweight devices that transmit a satellite-trackable signal as they make their arduous journey from breeding grounds in the UK south to Africa. Over the past five years, the signals of around 50 cuckoos have been helping a team of researchers at the British Trust for Ornithology (BTO) gain the first information on what happens to Africa-bound migrant birds after they have left the shores of the UK. The BTO's hope is that this will help solve the mystery of why the cuckoo population has halved in the UK in the past 20 years.

Dr Chris Hewson, who leads the BTO project, explains: "Before we started the work, all we knew was that we were seeing a continual drop in cuckoo numbers. We didn't know whether this was a result of changes in the UK breeding grounds, or of fatalities on the migration routes or in Africa. But, by tracking the birds, we now know which routes they take and the relative costs of each in terms of mortality, which has led us to begin to understand some of the causes of the decline."

These images are part of the first photo-narrative of the African landscapes in which the globally dwindling cuckoo population spend their winter months away from the UK. They were taken by Toby Smith, artist-in-residence at the University of Cambridge Conservation Research Institute.





In fact the cuckoo is not alone in facing an uncertain future, says Juliet Vickery at the RSPB's Centre for Conservation Science: "Around 70% of long-distant migrant bird species that winter in sub-Saharan Africa are declining. For most we don't understand why, but the causes are likely to be complex as they face loss of habitat, through human- and drought-related land use change, hunting and climate change, right across the flyway."

"We expect birds like cuckoos, swallows, swifts and nightingales to rock up here every summer but what if they don't arrive?" adds Professor Bill Adams from the Department of Geography. Four years ago, he teamed up with Vickery, Hewson and researchers at the Department of Zoology to review all of the information available on the fate of the birds in a project funded by the Cambridge Conservation Initiative.

It became clear that really very little was known. In particular, there were few comparative studies on the effects of land use change in regions in Africa frequented by many of the 2.1 billion birds that migrate from Europe during the non-breeding season.

"These regions are areas where poverty makes the welfare of urban and rural people the policy priority," adds Adams. "Often

what is good news for people – adapting land to create work and food – is bad news for birds unless there is a sophisticated understanding of the implications of habitat requirements. Only then can we hope that decision making can support nature too."

Adams and others view Africa as a major gap in knowledge about land use and birds: "In Europe we know a lot about how and why people use rural land, and what this means for migrant birds. But we don't know much about rural African landscapes in which birds spend the winter."

However, a few months ago, an idea began to take shape that could provide a step towards bridging this knowledge gap.

Smith had just taken up his role as artist-in-residence at UCCRI. Speaking to Adams and Hewson about the fate of the cuckoos, he was fascinated: "I wondered whether I could follow the cuckoos to Africa. No-one really knows what the cuckoo finds there – how people fashion a landscape that's either friendly or unfriendly for cuckoos. I wanted to contribute to the research project by providing 'eyes on the ground' at their journey's end."

"The most important element in land use change in this region is the rural household," explains Adams. "And the opportunity to present the landscapes



Images

Landscapes with transitions between woodland, scrub and grassland suit the cuckoo

in photographs that help us understand woodland management and agricultural practice was very attractive."

Actually spotting a cuckoo, however, was unlikely, as Smith explains: "The tracking data is accurate enough to pinpoint where the cuckoos are to within 500 m, but there's a delay between the signal being transmitted by the bird's tag and being accessible to us in the field, and the forest terrain is vast.

"Seeing a bird would have been epic but, from a visual perspective, it wouldn't have told us anything new. I wasn't there as a birdwatcher, I was there as a documentary photographer. I was more interested in experiencing and engaging with the natural and social landscape of these birds. Very little scientific attention had been paid to this area – even Gabon's most prolific birder hadn't been there in 35 years."

And so in January 2016, Toby Smith and Malcolm Green, an oral storyteller, arrived in Gabon with hammocks and a petrol stove, hired an off-road vehicle and set off to bush-camp for almost two weeks. Their trip was funded through Flight Lines (a joint project between the BTO and the Society of Wildlife Artists), the Economic and Social Research Council Impact Acceleration account, and Smith and Green themselves. They spoke to hunters and villagers, asking what they knew of the cuckoo – "we used photographs and bird-song recordings to help identify any interactions" – and Smith photographed the cuckoo's habitat of forest margins and grasslands on the Batéké Plateau.

Back home, he opened up his photo editing and curating process to conservation specialists like Chris Hewson and other partners in the Cambridge Conservation Initiative – a unique collaboration between the University of Cambridge and biodiversity conservation organisations within the newly opened David Attenborough Building.

"Conservationists have a specific aesthetic interpretation of pictures, and so Chris and others needed to be really involved in the process of selecting which images told an important part of the cuckoo's story.

"Generally, what I found in Gabon was encouraging. The density of people is so thin that even if the bird was hunted within 40 km of each village there are still huge areas available. It's an area of great biodiversity and the villagers

are not hugely aware of the cuckoo among the general flora and fauna.

“There was an incredible mosaic of gallery forest where the water table is accessible beneath the sand. And there were abrupt transitions between savannah landscape and forested landscape – there’s a lot of forest edge. From what we know about cuckoo behaviour this suits them to a T.”

“However, future land use change in the Gabon is likely to accelerate,” says Hewson. “To have Toby’s eye-witness account now is really important. Even finding that people rarely see cuckoos there is instructive for us – it shows what we are going to be up against when we go out there. It helps us to piece this together with knowledge of migration routes, to provide a more fully formed idea of what happens to the cuckoo for the major part of its annual cycle.”

Recently, the BTO tracking project has shown for the first time that cuckoos use two different routes to reach Africa (through Italy and across the Sahara, and through Spain and around the edge of West Africa) and that the Spanish route is associated with greater mortality. The team has found that the use of this route within local breeding populations correlates with population decline. In an article recently published in *Nature Communications*, the researchers suggest that this might be linked to severe droughts in Spain, such as in 2012, and raise concerns that a more recent drought in Italy might have further repercussions for the declining cuckoo population.

“Ultimately more research is vital,” says Adams, who has a joint project with Vickery starting next year in Ghana to look at the drivers of land use change and the impact on birds. “My hope is that Toby’s work will contribute towards a common understanding between ornithological researchers and development researchers about the way people and birds share landscapes.”

Meanwhile, as of March 2016, and after no signal for seven weeks, Disco Tony “popped back up” according to the BTO’s blog of each of the cuckoo’s whereabouts. Traced to the Central African Republic, he has begun his long journey back to the bog in Wales.

Why the name Disco Tony? The Welsh bog in which he was tagged was a particularly challenging environment to work in, with high tussocky grass. To reach the captured cuckoo, bird-ringer Tony Cross had to do a hopping, balancing, disco dance of a run. Naming the cuckoo Disco Tony seemed only appropriate.

www.bto.org/science/migration/tracking-studies/cuckoo-tracking/disco_tony



Credit: All images, Toby Smith

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“Toby’s work will contribute towards a common understanding between ornithological researchers and development researchers about the way people and birds share landscapes”

BEHIND THE “HONEY



Credit: Kip Loades

Claims that the UK has become a “honeypot” nation for European Union (EU) migrants attracted by the country’s welfare system have become a key issue in the debate about the UK’s membership of the EU. But what are the experiences of EU migrants working in the UK, and their attitudes to employment and social security, ask researchers in the Faculty of Law?

In his letter to the President of the European Council on 10 November 2015, David Cameron outlined plans to curb EU migration to the UK by “reducing the draw that our welfare system can exert across Europe”.

The Prime Minister is referring to what one *Daily Mail* headline described as the UK’s benefits “honeypot”: the idea that this country’s welfare system attracts migrants from across Europe, who export benefits and claim tax credits to supplement low family incomes back home, at the expense of the UK taxpayer.

Cameron’s consequent negotiation of an “emergency brake” on in-work benefits for EU migrants has done little to quell the heated rhetoric. Those on either side of the ‘Brexit’ debate continue to jump on the issue – lauding Cameron’s “clampdown”, or decrying “benefit tourism” in a nation “creaking at the seams” – as June’s EU referendum approaches.

However, critics argue that the government has been consistently unable to provide compelling evidence that this is the case. A response to a recent Parliamentary question on the amount spent on benefits to EU migrants was simply: “the information is not available”.

Two researchers in EU law from Cambridge’s Faculty of Law, Professor Catherine Barnard and Dr Amy Ludlow, are aiming to fill some of this knowledge gap. One of the ways they are doing so is by capturing the opinions and experiences of the migrants themselves.

For the EU Migrant Worker Project, launched earlier this year with funding

 Barbara, interviewed for the EU Migrant Worker Project, has two University degrees but her prospects in Spain are such that she feels it necessary to look for work elsewhere

from the ‘UK in a Changing Europe’ programme run by the Economic and Social Research Council, the researchers have set about talking to those who moved from the continent to make the UK their home.

By combining interviews with new methodologies for analysing what available data there is, Barnard and Ludlow hope to build a significant base of evidence about EU migrants’ experiences of, and attitudes towards, Britain’s employment and social security systems.

So far, fieldwork has involved visiting venues as diverse as further education colleges, shops, churches, farms, and mother and toddler groups, as well as citizen’s advice bureaux and job centres, sitting down with those who have just arrived and those who have built businesses and raised families here.

The researchers have consulted with economists and held roundtable discussions with current and former MPs. They are also travelling to Spain and Poland to shoot short documentaries, following migrants’ journeys to the UK for work and study.

“The image of the benefits-scrouring migrant is potent, but there is no evidence that it is widespread,” says Barnard. “To date, the people we have interviewed described the main factors driving EU nationals to the UK as work and opportunities for personal development, including the learning of English. Receipt of benefits – the details of which are often hazy to migrants – does not appear to feature.”

However, the perception of migrants “milking Britain’s benefits” casts a long shadow, not just over the EU membership

“HONEYPOT” HEADLINES



debate, but also over the lives of those who have settled here, says Ludlow.

“One Polish national, who moved here almost ten years ago after her husband was headhunted by a British firm, described to me the moment her young son’s friend told him his school place is ‘supposed to be used by an English child’.”

She says this is just one example of the xenophobia reported by migrants, often fuelled by insecurities in the native population – whether around jobs, housing or healthcare – and stoked by the benefits “honeypot” narrative.

This insecurity, mixed with Britain’s deep-rooted ‘island mentality’, might partly explain the UK’s firmer response to EU migration, says Ludlow, than those of many EU neighbours. She recalls being in a Spanish town recently and encountering a sign in English advising Brits to claim benefits, and how to go about it. “That’s just not something you’d see reported in the press here.”

“The idea of EU citizenship, that if I go to another EU country I expect to be treated like a citizen of that nation from day one, is a powerful idea, but it’s an idea that’s still a very long way off in policy terms.”

Most interviewees expressed the idea that benefits should be earned through work in the host state. The researchers have found a reluctance among EU migrants to enforce their EU law claims to exportable benefits, such as child benefit – practices which they feel are “abusive”.

Yet, claiming social rights, including welfare, can be seen as an expression of citizenship. As one interviewee remarked: “When someone uses

the welfare state, the State gains a citizen. We use social rights to become integrated. We don’t become integrated and then use social rights.”

While media reports have suggested a spike in sales of citizenship textbooks, responses from those interviewed have been mixed. Some EU migrants spoke of applying for citizenship out of a concern for their future if Brexit should occur, but many have no desire to sever ties with their homeland, and resent feeling forced to choose.

“The UK is not the land of milk and honey, and many migrants will simply take their skills elsewhere,” says Ludlow. One interviewee, who is returning to Poland for a “better quality of life”, told researchers: “I’m not interested in staying in the UK just because it’s possible.”

Another EU migrant, a dentist working in East Anglia, said that people will move to where they are welcome. “Migrants working in the fields and in lower level jobs will move on. There are plenty of fields in France and Spain. But the British businesses that rely on the migrants will close.”

And, in agriculture alone, those businesses are plentiful, says Ludlow. “We spoke to farm managers who said they need around £1.5 million of labour annually, and it all comes from the continent.”

The researchers say there is a policy mismatch between stopping migrants from claiming benefits yet raising the living wage, as it is wages that incentivise migrants, not benefits.

They also argue that if we are really concerned about EU migrants ‘undercutting’ the domestic workforce, there should be a greater focus on

“We spoke to farm managers who said they need around £1.5 million of labour annually, and it all comes from the continent”

making it possible for migrant workers to enforce their employment rights. Barnard and Ludlow’s analysis of the limited available data, combined with fieldwork, suggests that EU migrants use UK employment tribunals over 85% less than would be expected, given the size of the workforce they represent.

Under current EU law, EU migrants have rights to equal treatment in their terms and conditions of employment as those offered to domestic workers. However, this exists “more ‘on paper’ than in practice”, say the researchers.

Throughout 2016, Barnard and Ludlow will continue to explore the hopes, fears and experiences of EU migrant workers coming to the UK, and what it is like to look for work and be employed in the UK. “We hope to increase our understanding of EU and domestic law as it works in practice,” adds Ludlow, “and to inform public opinion in anticipation of the referendum in June and beyond.”

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There's a nationwide shortage of suitable organs for transplanting – but what if some of those organs deemed 'unsuitable' could be rejuvenated? Researchers at Addenbrooke's Hospital have managed just that – and last year gave two patients an unexpected Christmas present.

In a room in the Department of Surgery, a kidney sits inside a chamber connected to tubes and monitors. Solutions and gases are pumping through it and urine is coming out.

In fact, the chamber in itself is not particularly special – it's an off-the-shelf machine used for cardiac bypass surgery in children: it's how it has been adapted and the new uses it has found that make it so significant. This machine is able to rejuvenate kidneys deemed not fit for transplant, making them fit and healthy again – and suitable for a recipient.

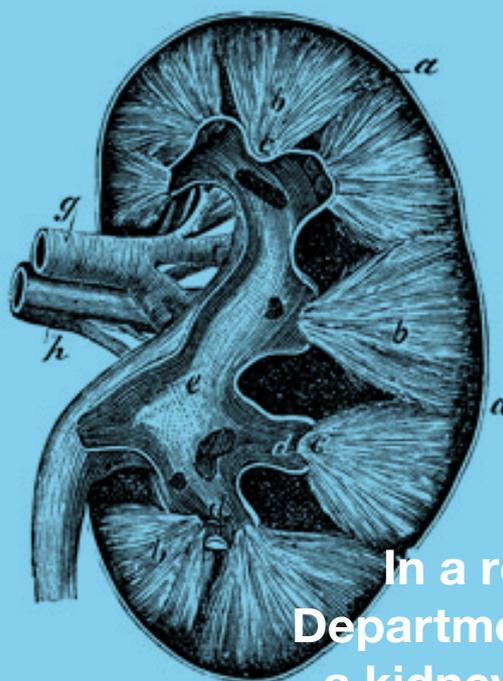
Professor Andrew Bradley, Head of the Department of Surgery, is quick to point out that it is his team at Addenbrooke's Hospital, part of Cambridge University Hospitals – particularly Professor Mike Nicholson and Dr Sarah Hosgood – who should take all the credit for this machine, which they refer to as an organ perfusion system.

There is a chronic shortage of suitable organs for transplant and something needs to be done. To help address the problem, in December 2015, Wales became the first country in the UK to make organ donation an 'opt-out' system – in other words, doctors would remove the organs from deceased individuals and provide them for use in sick patients unless the individual had explicitly refused consent before their death.

Unfortunately, not every donated organ is suitable for transplant – in the case of kidneys, for example, around 15% are deemed unsuitable. This can be for a variety of reasons, including the age of the donor, their disease history and the length of time the organ has been in cold storage.

"Grading organs is not an exact science – it's a mixture of factors about the circumstance in which it became available, its storage and how it looks to a trained eye," says Nicholson. "This isn't good enough, particularly if it means we're losing some potentially suitable organs."

What if there was a way of taking these organs and assessing them systematically? And to take it a step further, could some of them even be rejuvenated? Before coming to



In a room in the Department of Surgery, a kidney sits inside a chamber connected to tubes and monitors

“As the perfusion solution is being circulated, the kidney will begin to function”

Cambridge, Nicholson and Hosgood developed a system while at the University of Leicester that effectively recirculates essential nutrients through the kidney, bringing it back to life.

“We use a combination of red blood cells, a priming solution, nutrients, protective agents and oxygen,” explains Hosgood. “We pump this through the kidney while maintaining a temperature close to our body temperature. It mimics being in the body.”

As the perfusion solution is being circulated, the kidney will begin to function and produce urine. By analysing the contents of this urine and monitoring blood flow, doctors can see how the kidney is performing and whether it might make a viable transplant organ. After just a 60-minute perfusion, the kidneys are resuscitated and are potentially ready for transplantation.

This is no longer just an experiment: since moving to Cambridge, with funding from Kidney Research UK and the National Institute for Health Research, the team has been able to take kidneys rejected from other transplant centres, resuscitate and assess them, then transplant them. In December last year, two individuals on the organ transplant waiting list received the perfect Christmas present courtesy of the Cambridge team: a new kidney.

So far, the team has taken five discarded kidneys and managed to rescue three. “We’re hoping to process another hundred over the next four years,” says Hosgood, who is also working with centres in Newcastle, Edinburgh and at Guy’s Hospital in London, in the hope of replicating their success.

The current kit, which was not purpose-built for organ perfusion, is bulkier and clumsier than ideal, so the team is currently fundraising to help design a dedicated machine, in collaboration with colleagues from the Department of Engineering. “It’s not very mobile, so we couldn’t use it to help resuscitate organs in transit to other centres.”

Nicholson and Hosgood’s success has spurred on other colleagues. Professor Chris Watson describes himself as “piggybacking” on their work to develop a technique for perfusing livers. The situation for liver transplants is even more serious than it is for kidneys: as many as one in five patients on the waiting list will die before a liver becomes available.

So far, his team has taken 12 livers, all but one of which had been rejected by other centres, and successfully resuscitated and transplanted them using a system that builds on the pioneering work of his two colleagues.

“There’s a scene in the Woody Allen film *Sleeper* where Allen’s character stumbles across a 200-year-old Volkswagen Beetle and manages to start it first time,” he says. “The liver is like that. You take it out of cold storage and expect it to start first time. By first assessing it on our machine, we can be more confident it will work first time.”

In some ways, this has proved more of a challenge than it did for kidneys, he adds. “With kidneys, you can put them in the machine for an hour, resuscitate them and then transplant them. If it doesn’t work immediately, the patient stays on dialysis until it picks up. With a liver, it takes longer to analyse and resuscitate the organ, and if it doesn’t work it’s a disaster for the patient.”

Now that the team has successfully revived and transplanted kidneys and livers, this is by no means the end of the story. There is still much work to be done to further improve the organ – and hence improve the function and prolong survival, says Hosgood.

Once transplanted, organs face a battle with the body’s immune system, which recognises its new occupant as a foreign body. This is one reason why the perfusion system uses only red blood cells, not white – to do so would risk an inflammatory response that could damage the organ.

“Of course, as soon as you transplant the kidney, it will face a

similar inflammatory response, but by then it should be in an improved state and able to cope better with what the body throws at it,” she explains. The Department is in the process of recruiting 400 patients for a randomised controlled trial to test this technology.

The perfusion system also enables therapies to be given directly to the kidney. This ensures optimal delivery of the treatment to the targeted organ and avoids any side effects in the patient. One promising avenue of research, in collaboration with Professor Jordan Pober at Yale University (USA), is the use of nanoparticles that target the endothelial cells in the lining of the kidney. These cells play an important role in the inflammatory response after transplantation. “The delivery of nanoparticles in this way may reduce damage to the organ after transplantation,” she adds.

The shortage of suitable organs is not going away. Not even a UK-wide ‘opt-out’ system is likely to completely eradicate the problem. If anything, the crisis is likely to get worse – the flipside of good news stories such as fewer road traffic fatalities and better medicines that reduce the number of young people dying early. The team recognises that the system alone is not the answer, but it brings a new relevance to the old adage “waste not, want not”.

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Fingerprinting rare earth elements from the air

Next time you use your mobile phone, spare a moment for the tiny yet vital ingredients that make this and many other technologies possible – the rare earth elements (REEs).

Used in computers, fibre optic cables, aircraft components and even the anti-counterfeiting system in euro notes, these materials are crucial for an estimated £3 trillion worth of industries, with demand set to increase over the coming decades.

Currently, more than 95% of the global demand for the REEs is met by a single mine in China. The security of the future supply of these 17 critical metals, which include neodymium, europium, terbium, dysprosium and yttrium, is a major concern for European governments, and the identification of potential REE resources outside China is seen as a high priority.

Over the past year, Drs Sally Gibson, Teal Riley and David Neave have been working together through a University of Cambridge–BAS Joint Innovation Project (see panel) on a remote sensing technique that could aid the identification of REEs in rocks anywhere in the world. The project brings together expertise in remote sensing, geochemistry and mineralogy from both institutes to take advantage of the properties that make the metals so special.

“Despite their name, the rare earth elements are not particularly rare and are as abundant in the Earth’s crust as elements such as copper and tin,” explains Riley from BAS. “However, to be extractable in an economic way, they need to be

concentrated into veins or sediments.”

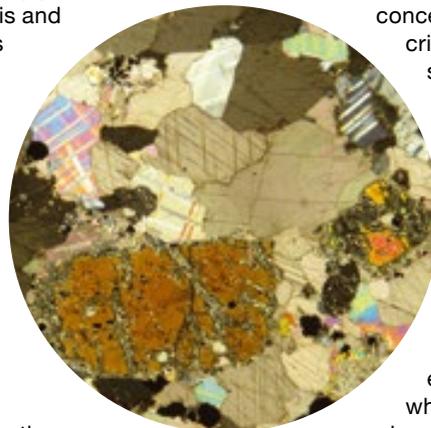
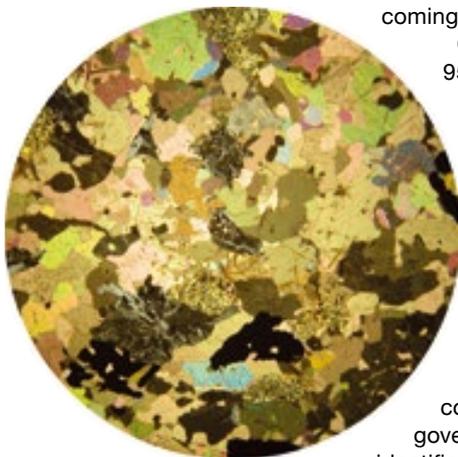
It’s the identification of these concentrations that is critical for the future security of supply.

REEs all have an atomic structure that causes them to react to photons of light through a series of electronic transitions. This gives them the magnetic and electrical properties for which they are prized in plasma TVs, wind turbines and electric car batteries. And

it also means that for every photon of light they absorb, they reflect other photons in a unique way – it is this property that the researchers have latched onto as a means of tracking them down.

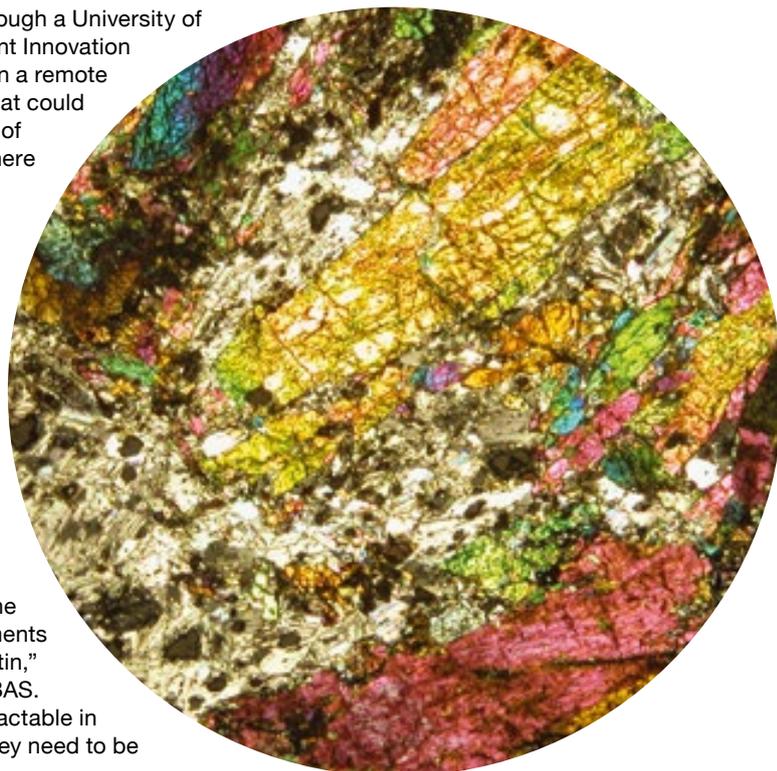
“The light they reflect is so specific that it’s like a fingerprint, one that we can capture using sensors that pick up light emissions,” explains Gibson, from Cambridge’s Department of Earth Sciences. “The difficulty, however, is that in naturally occurring rocks and minerals, the rare earth element emission spectra are mixed up with those of other elements. It’s like looking at overlapping fingerprints – the challenge was to work out how to tease these spectral fingerprints apart.”

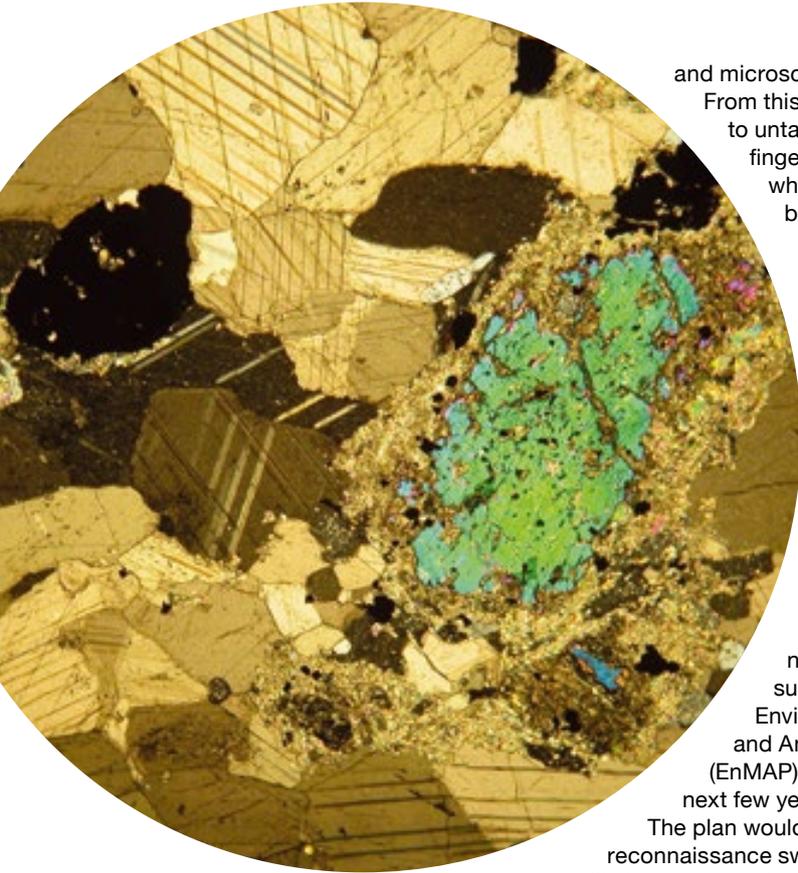
Gibson has over 20 years’ experience



 Microscopic images of rocks hosting high concentrations of rare earth elements

Vital to many modern technologies yet mined in few places, the ‘rare earth elements’ are in fact not that rare – they are just difficult to find in concentrations that make them economic to mine. Researchers from Cambridge University and the British Antarctic Survey (BAS) are investigating whether the remarkable properties of these materials can be used to track them down from the air.





investigating how REEs are generated during the melting of the Earth's mantle. "Collective understanding of the geological make-up of the world is now good enough that we know where to look for these rocks – at sites of a certain type of past tectonic activity – but even then it's difficult to find them."

Riley is the head of the Geological Mapping Group at BAS – his job is to "map the unmapped" areas of the polar region to understand the geological evolution of the continent. Much of his work depends on being able to develop new ways of interrogating satellite- and aircraft-based remote sensing data. "It became a frustration that we could collect data and say generally what was on the ground but that we couldn't define individual fingerprints, and so we developed the analytical tools to do this."

Gibson and Neave gathered rocks containing REE-bearing minerals from around the world – sourced from mining companies, museum collections and universities. One such source was the Harker Collection housed in the University's Sedgwick Museum of Earth Sciences. This collection contains specimens of minerals and rocks rich in REEs that were collected decades previously by geologists who were unaware of their economic importance.

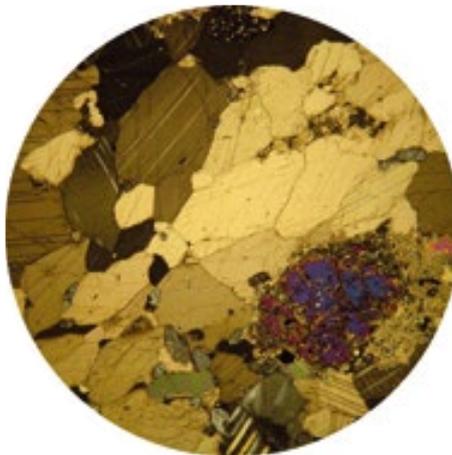
Neave analysed the emission spectrum of each rock and related this to its gross

and microscopic composition.

From this information he began to untangle the individual fingerprints, resulting in what the researchers believe is the most comprehensive 'spectral database' of REEs in their natural state – in rocks.

The next goal is to use this spectral database as a reference source to track down deposits from the air. "Although data from aircraft is now good enough to be analysed in this way, we are waiting for new satellite missions such as the German Environmental Mapping and Analysis Program (EnMAP) to be launched in the next few years," explains Riley.

The plan would then be to carry out reconnaissance sweeps of the most likely terrains and explore the possibility of mining these areas. "Our hope is that this research will help to create an internationally unique and competitive capability to map these surprisingly common – yet difficult to find – materials," adds Gibson.



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Aurora Cambridge

The search for rare earth elements is one of a host of ongoing projects between the University and BAS. Like these, a new centre – Aurora Cambridge – will reflect the ethos that innovation developed for the Antarctic is transferable to a global setting.

Aurora Cambridge aims to generate new research and entrepreneurial activity focused on climate change and challenging environments through academic, business and policy partnerships. It will be located at BAS in Cambridge and has been funded by the National Environment Research Council with support from the University.

The building is due to open in 2017; however, 27 University of Cambridge–BAS Joint Innovation Projects are already under way with funding from the Higher Education Funding Council for England – including the development of mapping technologies for rare earth elements led by Drs Sally Gibson and Teal Riley.

Other projects include research on cold-adapted enzymes with potential applications in the biotech industries, remote sensing for conservation of seabirds and marine mammals, and the measurement of coastal vulnerability through sea-level rise. Many involve external industrial partners and other research institutions as well as researchers from BAS and 12 University departments.

"The collaborative projects demonstrate not only the importance of research technology to the Antarctic but also their transferability beyond its shores to a global setting," explains BAS Director of Innovation Dr Beatrix Schlarb-Ridley. "The SPECTRO-ICE project, for instance, has brought scientists at BAS who are concerned with monitoring the atmosphere above the ice cap together with physicists and mathematicians who are working hard to avoid seeing the atmosphere in their study of the stars – both use similar techniques and need to operate advanced instruments at difficult locations."

"This is just the beginning," says BAS Director Professor Jane Francis. "The new innovation centre will help us to extend the range of fruitful partnerships with academia, business, policy makers and the third sector to create tangible benefits for society."

www.bas.ac.uk/aurora-cambridge



“Houses are built to be lived in but also to be looked at – and you only have to switch on your television to see how much they fascinate us”

It’s black and white, silent and just short of ten minutes in length. But D.W. Griffith’s 1909 classic *The Lonely Villa* inspired Dr John David Rhodes, Director of Cambridge’s new Centre for Film and Screen, to look at the role and meaning of the house in American cinema.

The Lonely Villa tells the story of four women subjected to a terrifying break-in by intruders. A woman barricades herself and her daughters into the house as her absent husband, alerted by a phone call, hastens to their rescue. In the opening shot, the villains are seen lurking in the shrubbery of the handsome all-American home that stands in splendid isolation, an icon of the property-owning dream.

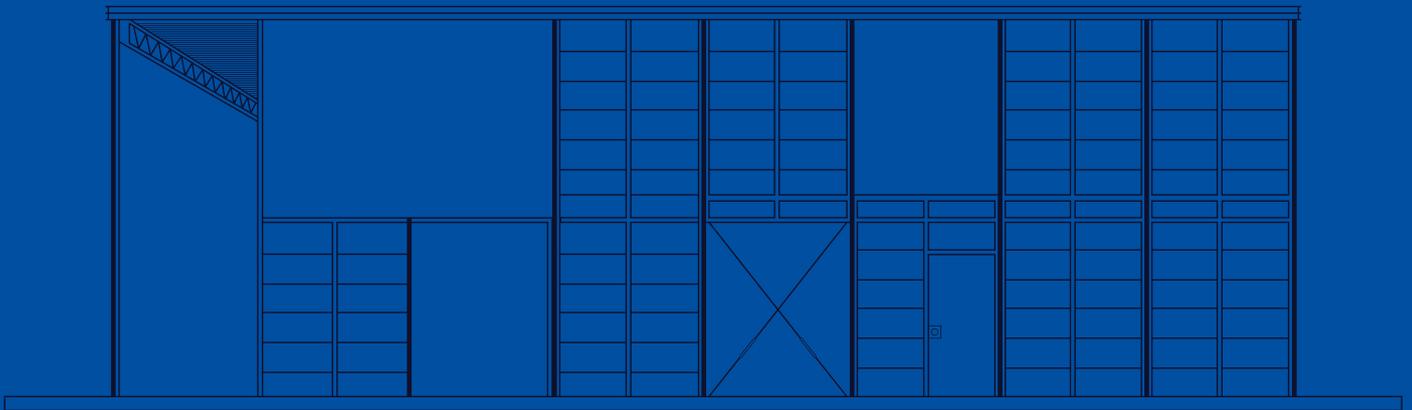
Rhodes’ exploration of the house in American cinema has taken him deep into the history and theory of both film and architecture, and will result in a book due for publication in 2017. He is Director of the newly launched Centre for Film and Screen, which brings together researchers from subjects as diverse as English, philosophy, history of art, architecture and languages, and continues a tradition of teaching and research on the subject of film since the 1960s.

“Houses are built to be lived in but also to be looked at – and you only have to switch on your television to see how much they fascinate us,” he says. “In watching cinema, too, we are forever looking at and into people’s houses. Cinema’s preoccupation with the house stems from cinema’s strong relation to realism and to the representation of human lives, a large portion of which plays out in domestic interiors.”

Central to Rhodes’ research into films that range from *Meet Me in St Louis* and *Gone with the Wind* to *Psycho* and *Citizen Kane* is the idea of property and possession as well as their opposites – alienation and dispossession. It’s a theme that flows through the cinematic experience right to the temporary possession of the seat in which the viewer watches a film and enters the intimate spaces of other people’s lives. “Property reigns in many aspects of the cinema experience,” he says. “Not just in the drama unfolding on the screen itself but also in the process of film-making, practices of production, distribution and exhibition.”

Rhodes suggests that the pleasure we take in immersing ourselves in the visual and sensual experiences of entering other people’s worlds has an antecedent in country house tours and, most specifically, the collections known as ‘cabinets of curiosities’. Objects acquired to display and impress, these museum-like collections are examples of belonging and, by the same token, of not belonging. “At the heart of visual pleasure is a constant negotiation of property boundaries,” says Rhodes. “It’s a question of mine but not yours – of inviting in yet keeping out.”

Revealed to a chosen few guests, cabinets of curiosities and their modern equivalents speak powerfully of their owner’s taste. A short film titled *House: After Five Years of Living* (1955) perfectly encapsulates the house as an object of desire and as a container for carefully curated possessions. Directed by designers Charles and Ray Eames, it shows their modernist house – one they



designed themselves – in a series of stills that venerate this landmark building and its collection of modern and folk art, textiles and design objects. Neither of its owners appears yet their presence is palpable through the framing, shot by shot, of the house they created to work so beautifully in its Californian context.

Ownership is not confined to buildings but extends to those who live and work in them. Rhodes says that his thesis is implicitly feminist. His forthcoming book will draw attention to the ways in which, in film and in real life, women are forced into uncomfortably close relationships with the home, becoming part of the same parcel of ownership.

An even more tightly binding relationship is played out between servant and home, particularly in the representation of African American slavery in the American South following the Civil War. Two thirds of the way into *Gone with the Wind*, the servant girl Prissy looks up at her employers' newly constructed mansion and exclaims: "We sure is rich now!" The viewer is apparently invited to laugh both at her delight and at her naivety, and in a manner that only

repeats the film's explicit racism. Yet the spectator is also the butt of this joke.

"This shot is a kind of 'hall of mirrors' of property relations," says Rhodes. "The cinema audience looks at the image which was Metro-Goldwyn-Mayer's property. Inside the image, the servants gaze up at the property of the house. But if we look carefully we see that there is no house there: what they are really looking at is either a painted background or else a matt painting inserted in the post-production process. Whether or not the image was there when the scene was shot, what they are looking at is a 'prop'."

The word prop is, of course, an abbreviation for property. The house, as the ultimate prop, takes many forms, its physical form acting as a powerful pointer. The mansion and the bungalow, the rambling shingle and stick-style residence, the modernist home with its picture windows: all convey messages (about status, class, race, politics) and shape the action that takes place within them.

"In much of the US, the possession of land, even if it's a tiny strip of grass separating one house from another, is

fundamental to a feeling of ownership. The bungalow was initially seen as a space for easeful, convenient living – but this modest home quickly came to spell failure," says Rhodes. "If you think about entrances and exits, a suburban home with a hallway allows for a gradual transition from outside to inside while a bungalow offers none of that dignity. The cramped space of the bungalow leads to too much intimacy and to uncomfortable confrontations."

Dwelling places are objects of desire – especially so in the affluent Western world. Our homes absorb our money and eat into our time: perhaps, in the process of acquisition, they own us just as much as we own them. As backdrops to our lives, they tell stories about the kind of people we are and would like to be. In film, and on the screen, houses convey multiple meanings – not just about class and status but also about childhood and our relationship with history.

When a house is broken into, a dream is shattered. In Griffith's *The Lonely Villa*, the ruffians are hampered by the solidity of the house's doors and the weight of the furniture pushed up against them. All ends well when the mother and daughters are rescued, just in time, by the man of the house. But property is fragile and, in the final reckoning, all ownership is a question of controlling impermanent and shifting borders.

Centre for Film and Screen:
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Time travelling to the mother tongue

The sounds of languages that died thousands of years ago have been brought to life again through technology that uses statistics in a revolutionary new way.

No matter whether you speak English or Urdu, Waloon or Waziri, Portuguese or Persian, the roots of your language are the same. Proto-Indo-European (PIE) is the mother tongue – shared by several hundred contemporary languages, as well as many now extinct, and spoken by people who lived from about 6,000 to 3,500 BC on the steppes to the north of the Caspian Sea.

They left no written texts and although historical linguists have, since the 19th century, painstakingly reconstructed the language from daughter languages, the question of how it actually sounded was assumed to be permanently out of reach.

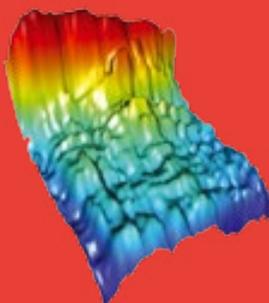
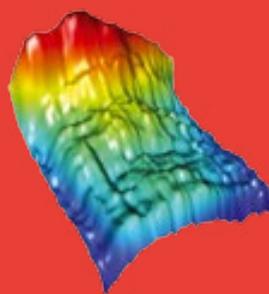
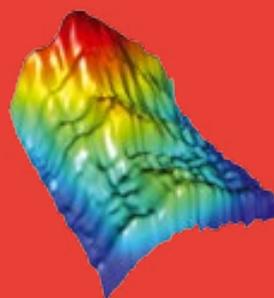
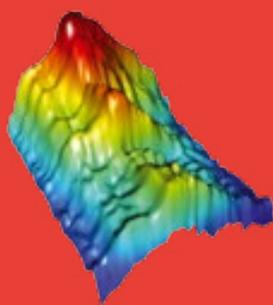
Now, researchers at the Universities of Cambridge and Oxford have developed a sound-based method to move back through the family tree of languages that stem from PIE. They can simulate how certain words would have sounded when they were spoken 8,000 years ago.

Remarkably, at the heart of the technology is the statistics of shape.

“Sounds have shape,” explains Professor John Aston, from Cambridge’s Statistical Laboratory. “As a word is uttered it vibrates air, and the shape of this soundwave can be measured and turned into a series of numbers. Once we have these stats, and the stats of another spoken word, we can start asking how similar they are and what it would take to shift from one to another.”

A word said in a certain language will have a different shape to the same word in another language, or an earlier language. The researchers can shift from one shape to another through a series of small changes in the statistics. “It’s more than an averaging process, it’s a continuum from one sound to the other,” adds Aston, who is funded by the Engineering and Physical Sciences Research Council (EPSRC). “At each stage, we can turn the shape back into sound to hear how the word has changed.”

FRENCH
un



ITALIAN
uno

Rather than reconstructing written forms of ancient words, the researchers triangulate backwards from contemporary and archival audio recordings to regenerate audible spoken forms from earlier points in the evolutionary tree. Using a relatively new field of shape-based mathematics, the researchers take the soundwave and visualise it as a spectrogram – basically an undulating three-dimensional surface that represents the shape of that sound – and then reshape the spectrogram along a trajectory ‘signposted’ by known sounds.

While Aston leads the team of statistician ‘shape-shifters’ in Cambridge, the acoustic-phonetic and linguistic expertise is provided by Professor John Coleman’s group in Oxford.

The researchers are working on the words for numbers as these have the same meaning in any language. The longest path of development simulated so far goes backwards 8,000 years from English *one* to its PIE ancestor *oinos*, and likewise for other numerals. They have also ‘gone forwards’ from the PIE *penkwe* to the modern Greek *pente*, modern Welsh *pimp* and modern English *five*, as well as simulating change from Modern English to Anglo-Saxon (or vice versa), and from Modern Romance languages back to Latin.

“We’ve explicitly focused on reproducing sound changes and etymologies that the established analyses already suggest, rather than seeking to overturn them,” says Coleman, whose research was funded by the Arts and Humanities Research Council.

They have discovered words that appear to correctly ‘fall out’ of the continuum. “It’s pleasing, not because it overturns the received wisdom, but because it encourages us that we are getting something right, some of the time at least. And along the way there have also been a few surprises!” The method sometimes follows paths that do not seem to be etymologically correct, demonstrating that the method is scientifically testable and pointing to areas in which refinements are needed.

Remarkably, because the statistics describe the sound of an individual saying the word, the researchers are able to keep the characteristics of pitch and delivery the same. They can effectively turn the word spoken by someone in one language into what it would sound like if they were speaking fluently in another.

They can also extrapolate into the future, although with caveats, as Coleman describes: “If you just extrapolate linearly, you’ll reach a point at which the sound change hits the limit of what is a humanly

reasonable sound. This has happened in some languages in the past with certain vowel sounds. But if you asked me what English will sound like in 300 years, my educated guess is that it will be hardly any different from today!”

For the team, the excitement of the research includes unearthing some gems of archival recordings of various languages that had been given up for dead, including an Old Prussian word last spoken by people in the early 1700s but ‘borrowed’ into Low Prussian and discovered in a German audio archive.

The longest path of development simulated so far goes backwards 8,000 years from English *one* to its PIE ancestor *oinos*

Their work has applications in automatic translation and film dubbing, as well as medical imaging (see panel), but the principal aim is for the technology to be used alongside traditional methods used by historical linguists to understand the process of language change over thousands of years.

“From my point of view, it’s amazing that we can turn exciting yet highly abstract statistical theory into something that really helps explain the roots of modern language,” says Aston.

“Now that we’ve developed many of the necessary technical methods for realising the extraordinary ambition of hearing ancient sounds once more,” adds Coleman, “these early successes are opening up a wide range of new questions, one of the central being how far back in time can we really go?”

I

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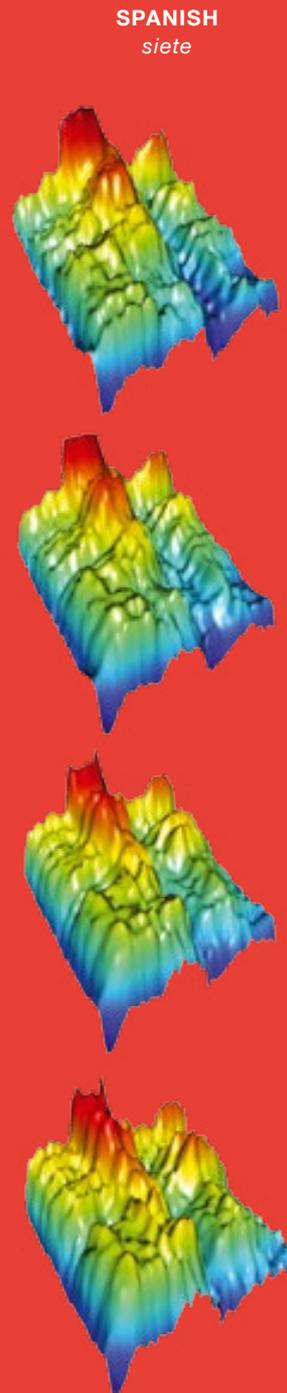
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Images

Spectrograms showing how the shape of the sound of a word in one language can be morphed into the sound of the same word in another language



Medical imaging reshaped

The statistics of shape are not just being used to show how different languages relate to each – they are also being used to improve the analysis of medical images.

Just as soundwaves have a shape that can be analysed using statistics, so do the patterns of neurons interacting with each other or the dimensions of the surface of a tumour. Now a new research centre will develop tools that use the mathematics of the shapes found in medical images to improve diagnosis, prognosis and treatment planning for patients.

The Centre for Mathematical and Statistical Analysis of Multimodal Clinical Imaging, one of five ‘maths’ centres recently funded by £10 million from EPSRC, is co-led by Aston and Dr Carola-Bibiane Schönlieb from the Department of Applied Mathematics and Theoretical Physics in Cambridge.

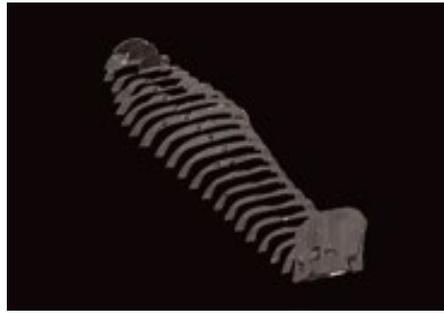
“The new methodologies will allow clinical medicine to move beyond one person reading single scans, to automated systems capable of analysing populations of images,” explains Schönlieb. “As a result, clinicians will have far greater scope to ask complex questions of the medical image.”

It’s already possible to extract statistical information from an image of a patient’s thigh bone, turn the data into a template for comparison with those from other people in the population, and then ask whether a particular shape of bone is more prone to being broken than others in the elderly.

Most organ scans split the image into many elements, which are then analysed voxel by voxel. “But complex structures like the heart and the brain should be analysed holistically,” explains Dr James Rudd, from the Department of Medicine, who leads the clinical interaction with the Centre. “The tools we are developing will enable the analysis of organs like the brain as single objects with millions of connections.”

The Centre brings together researchers and clinicians from applied and pure maths, engineering, physics, biology, oncology, clinical neuroscience and cardiology, and involves industrial partners Siemens, AstraZeneca, Microsoft, GSK and Cambridge Computed Imaging.

Things Uncovering the afterlife of ancient Egypt



This 'recycled' coffin bears an updated 'cv', a doodled eye and 3,000-year-old fingerprints, and is one of the treasures revealing its hidden secrets thanks to new research at the Fitzwilliam Museum.

Golden yellow and covered from head to toe in bright hieroglyphs in reds, greens and blues, the set of coffins belonging to Nespawershefyt was one of the very first gifts to the collection at the Fitzwilliam Museum. It was given by two members of the University in 1822, just a few years after the Museum was founded 200 years ago this year.

The outstandingly well-preserved artefacts contain valuable clues as to how Egyptian coffins were made and to the man who commissioned them. To uncover their hidden secrets, they've been studied using imaging techniques at the Museum, the Radiology Department of Addenbrooke's Hospital, part of Cambridge University Hospitals, and the Department of Engineering.

"The results were stunning and yielded a huge amount of information," says Julie Dawson, Head of Conservation at the

Museum. "The inner coffin box is made up of a multitude of pieces of wood, including sections from at least one older coffin. Wood was a precious commodity and the craftsmen were incredibly skilled at making these complex objects from sometimes unpromising starting materials."

Other surprises lay in wait: 3,000-year-old fingerprints, suggesting that the craftsmen moved the lid of the inner coffin before the varnish had dried; new job titles that were inscribed over old ones, presumably as Nespawershefyt rose in rank as a senior official; and even the odd doodle on the underside of a coffin box.

Nespawershefyt was clearly keen to prepare properly for his afterlife. "To us, this seems like a morbid preoccupation," adds Helen Strudwick, Egyptologist at the Museum. "In fact, it was an obsession with life and an urgent wish to ensure its perfected continuation."

The Fitzwilliam Museum is the art and antiquities museum of the University of Cambridge and is 200 years old this year.

www.fitzmuseum.cam.ac.uk

**Image**

Different imaging techniques have been used to analyse Nespawershefyt's coffin



The rise and fall and rise of cities



Why is Milton Keynes one of the most successful cities in the UK, and Dundee one of the least? What gives Leeds its economic edge over Liverpool? How did London survive the 1990s recession, going from boom to bust and boom again? Researchers are asking these questions and many more in the largest ever analysis of what makes cities thrive.

Arguably, everything about Milton Keynes is deliberate: its site, its transport, its housing, its business sectors, its jobs. From the moment of its 'birth' in 1967 as one of the country's 'new towns', Milton Keynes was planned as a whole. Over the past three decades, it has out-smarted every other city in the UK in terms of its annual average growth rate of output and employment.

Meanwhile, most of Britain's old industrial cities – Newcastle, Sheffield, Birmingham, Glasgow and Liverpool among them – underwent a dramatic slippage in growth from the beginning of the 1980s to the late 1990s. Although their decline has slowed, they still lag behind the national average in terms of economic growth.

Not so London. After years of relative decline, it has experienced a turnaround since the early 1990s, thanks to its flourishing financial sector and rapidly expanding business services. It even weathered the recent recession better than almost all other parts of the UK. It has become one of the fastest growing parts of country, and is predicted to pull further ahead of the rest of the country in the next decade.

This story of a 'great divergence' opening up between cities is being played out all across the UK, as well as elsewhere in the industrialised world. In the USA, for instance, the downturn in the fortunes of Detroit and Cleveland stand in stark contrast to boom cities like San Francisco and Boston. Recent efforts in the UK to rebalance the economy have included the 'Northern Powerhouse' investment to boost Manchester, Liverpool, Leeds, Sheffield and Newcastle.

"Cities have always had upturns and downturns. But for the first time in human history more than half of the world's population lives in cities and so now more than ever it's important to understand what it is that makes a city flourish," says Professor Ron Martin. "Adaptability and resilience may be today's buzzwords but this is the way that cities – and those making policies that affect cities – need to think to keep them working well."

Martin leads a major research project aimed at understanding transitions through boom, bust and austerity for UK cities, and the lessons that can be learned from the past 50 years of economic history that might help cities prepare for the decades ahead.

It will be the largest ever analysis of the post-industrial fortunes of the UK's cities. It builds on work that Martin and his team carried out for the UK Government Office for

Science (GoS) Foresight Project on the Future of Cities – the brainchild of Government Chief Scientific Adviser, Professor Sir Mark Walport.

"Cities matter to the UK," explains the GoS Future of Cities project. "They are the concentrations of the UK's population, trade, commerce, cultural and social life. They are also the sites where most of the UK's future growth, both population and economic, is forecast to occur. The UK's future is now closely linked to that of its cities."

The fastest growing cities over the past three decades have been those in the south of the country, linked with a downturn in manufacturing in the north and an increase in service industries in the south.

"Manufacturing still happens of course, and is still important to the economy of many of our cities," says Martin. "But the number of people working in manufacturing has fallen over the past 30 years because of increasing efficiency and productivity, and the rise of foreign competitors."

"It's a bit like buying stocks and shares – you wouldn't put all your money in one company because you risk losing everything"

The team's study for the Foresight Project looked at 63 cities across the UK. One finding was that the fastest growing cities over the past three decades were the new towns like Milton Keynes that had been deliberately planned and developed through post-war public policy. "In these cases, everything to do with a new settlement could be thought about holistically – an argument perhaps for focusing on expanded cities in the future."

But what about old industrialised cities? "There's a huge infrastructure in these cities and a lot of talent," says Martin. "We found that whereas some cities are experiencing a worsening of economic inequalities and failures, others have managed to reinvent themselves by growing new sectors – electronics, pharmaceuticals, finance, business support services. Those cities that hadn't managed to diversify, reorientate and adapt their employment sectors fared less well."

Martin cites Cambridge as an exemplar of diversification: "Cambridge is interesting because it is often held up as a high-tech cluster but in fact you can identify around

14 specialisms, with life sciences currently moving into pole position. The key is to keep branching into new areas."

He adds: "This shouldn't really come as a surprise. It's a bit like buying stocks and shares – you wouldn't put all your money in one company because you risk losing everything. The same goes here – you need a diverse economic structure to withstand shocks to the system."

Before this study, however, the data simply wasn't available to draw this conclusion. Martin's team worked with Cambridge Econometrics, business management consultants, who are specialists in building up city-level datasets from local data.

Now, with funding from the Economic and Social Research Council, the team has increased to include researchers at the Universities of Southampton, Newcastle and Aston, and the dataset they are building is the largest of its kind ever constructed for the UK: the growth, employment and economic structure of 75 cities, for four decades from 1971, with hopes eventually to look back to the mid-19th century. Ten cities have been chosen for an in-depth analysis of firm dynamics, local governance and public policy.

"Cities have come to dominate how we think and talk about economies, particularly as they navigate the turbulent and uncertain context of austerity and economic reform," says Martin. "There is little doubt that cities face an unprecedented and intense set of economic, social and environmental challenges. Our research as part of the Future of Cities project provided the first quantitative evidence that different cities demonstrate very different capacities to cope with and respond to challenges, and that these lead to diverse economic outcomes."

It's timely, he adds, to be considering what makes a city thrive, given the ongoing discussions by government on the business case for devolving central policy decisions and budgets to regions.

"In this context, while fiscal devolution is desirable, differences between cities could assume greater significance," says Martin. "If cities and regions take more control of the purse strings, they will need to know where best to invest resources to help them thrive. This research programme is ambitious but we are confident that we will be able to identify at least some of the keys to city economic success and how to maintain that success over time."

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The cities of today are built with concrete and steel – but some Cambridge researchers think that the cities of the future need to go back to nature if they are to support an ever-expanding population, while keeping carbon emissions under control.

Between them, concrete and steel are responsible for as much as a tenth of worldwide carbon emissions. Before they ever reach a construction site, both steel and concrete must be processed at very high temperatures – which takes a lot of energy. And yet, our cities are completely dependent on these two unsustainable materials.

“I fly back and forth a lot between the UK and the US, and I’d been harbouring a lot of guilt about the effect that had on my carbon footprint – I’d always assumed,

as many of us do, that air travel is a huge contributor to carbon emissions,” says bioengineer Dr Michelle Oyen of Cambridge’s Department of Engineering. “But the truth is, while the emissions caused by air travel are significant, far more are caused by the production of concrete and steel, which of course is what most cities are built from.”

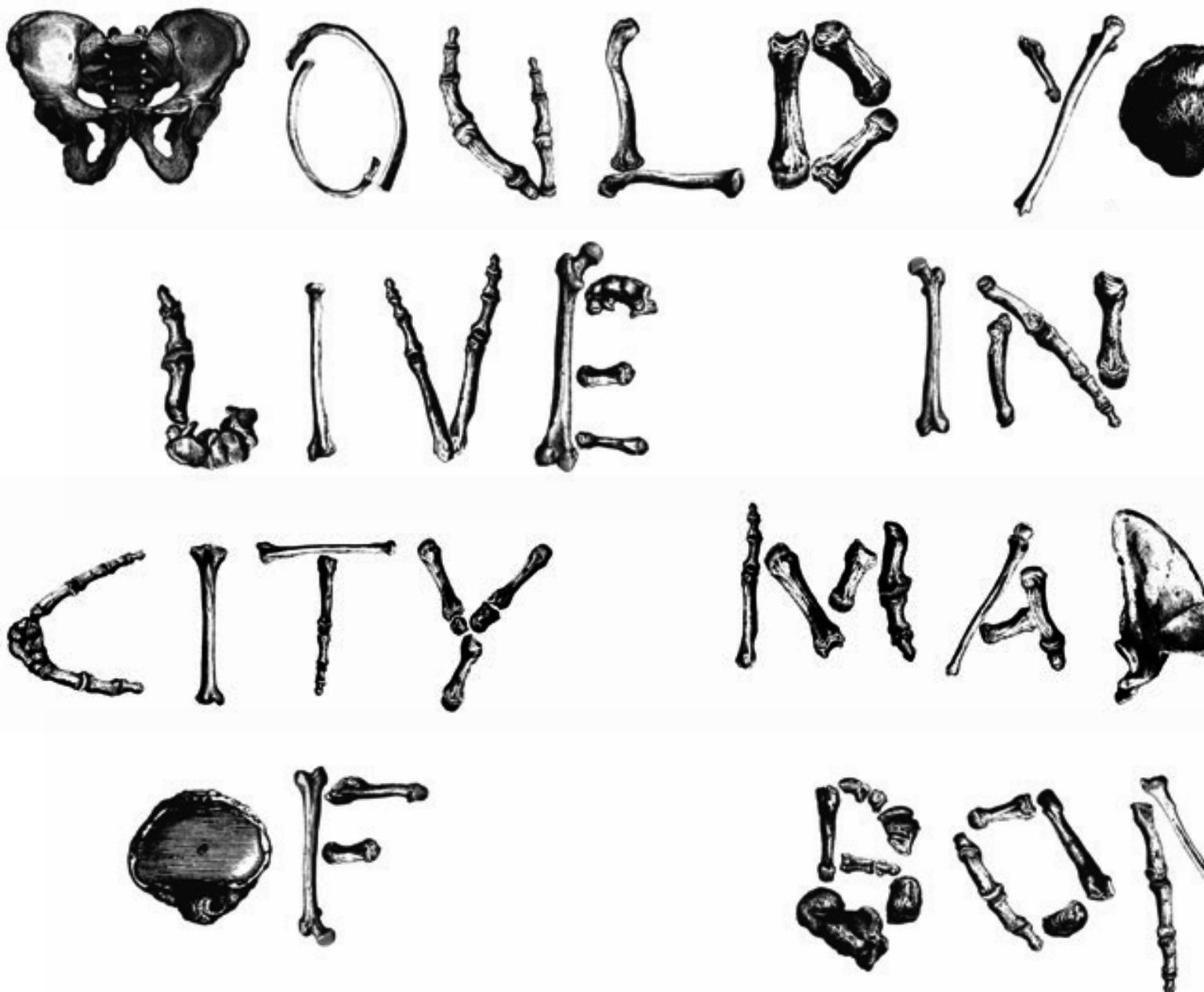
So what does that mean for cities of the future, as more and more of us live in urban areas? How can we continue to build while reducing carbon emissions?

Whereas some researchers are investigating ways of producing steel and concrete in more energy-efficient ways, or finding ways of using less, Oyen would rather turn the tables completely, and create new building materials that are strong, sustainable and take their inspiration from nature.

“What we’re trying to do is to rethink the way that we make things,” says Oyen. “Engineers tend to throw energy at problems, whereas nature throws information at problems – they fundamentally do things differently.”

Oyen works in the field of biomimetics – literally ‘copying life’. In her lab, with funding support from the US Army Corps of Engineers, she constructs small samples of artificial bone and eggshell, which could be used as medical implants, or even be scaled up and used as low-carbon building materials.

Like the real things, artificial bone and eggshell are composites of proteins and minerals. In bone, the proportions of protein and mineral are roughly equal – the mineral gives bone stiffness and hardness, while the protein gives it toughness or resistance to fracture. While



“Just because we can make all of our buildings out of concrete and steel doesn’t mean we should. But it will require big change”



bones can break, it is relatively rare, and they have the benefit of being self-healing – another feature that engineers are trying to bring to biomimetic materials.

In eggshell, the ratios are different: about 95% mineral to 5% protein, but even this small amount of protein makes eggshell remarkably tough considering how thin it is.

When making the artificial bone and eggshell, the mineral components are ‘templated’ directly onto collagen, which is the most abundant protein in the animal world. “One of the interesting things is that the minerals that make up bone deposit along the collagen, and eggshell deposits outwards from the collagen, perpendicular to it,” says Oyen. “So it might even be the case that these two composites could be combined to make a lattice-type structure, which would be even stronger – there’s some interesting science there that we’d like to look into.”

In her lab, Oyen and her team have been making samples of artificial eggshell and bone via a process that could be easily scaled up – and since the process takes place at room temperature, the samples take very little energy to produce. But it may be some time before we’re living in bone and eggshell houses.

For one, the collagen that Oyen needs to make these materials comes from natural (meaning animal) sources. One of the things she’s currently investigating is whether a non-animal-derived or even synthetic protein or polymer could be used instead of natural collagen.

“Another issue is the construction industry is a very conservative one,” Oyen says. “All of our existing building standards have been designed with concrete and steel in mind. Constructing buildings out of entirely new materials would mean completely rethinking the whole industry. But if you want to do something really transformative to bring down carbon emissions, then I think that’s what we have to do. If we’re going to make a real change, a major rethink is what has to happen.”

Dr Michael Ramage from the Department of Architecture is another Cambridge researcher who believes we need to expand our use of natural materials in buildings. Ramage has several ongoing research projects that are looking into the use of wood – one of the oldest building materials we have – for tall buildings.

Working with PLP Architecture and engineers Smith and Wallwork, Ramage recently delivered plans for an 80-storey, 300 m high, timber skyscraper to the Mayor of London. The proposals currently being developed would create more than 1,000 residential units in a 1 million square-foot, mixed-use tower and mid-

rise terraces, integrated into the Barbican in central London.

Like other natural materials, the primary benefit of using wood as a building material is that it is a renewable resource, unlike concrete and steel. Ramage’s research is also investigating other potential benefits of using wood for tall buildings, such as reduced costs and improved construction timescales, increased fire resistance and a significant reduction in the overall weight of buildings.

“If London is going to survive an increasing population, it needs to densify,” says Ramage. “One way is taller buildings. We believe people have a greater affinity for taller buildings in natural materials rather than steel and concrete towers. The fundamental premise is that timber and other natural materials are vastly underused and we don’t give them nearly enough credit. Nearly every historic building, from King’s College Chapel to Westminster Hall, has made extensive use of timber.”

The tallest timber building in the world at the moment is a 14-storey apartment block in Bergen, Norway, but Ramage foresees future cities where timber skyscrapers sit alongside those made of concrete and steel.

“Future cities may not look a whole lot different – you may not know immediately if you are in a timber, steel or concrete building,” says Ramage. “But cities might be a whole lot quieter, as most timber buildings are built off site, and then just assembled on site, and use roughly a fifth as much truck traffic as equivalent concrete buildings. In other words, what needs to be delivered in five trucks for a concrete building can be delivered in one truck for a timber building. That’s an incredible advantage, for cost, for environment, for traffic and for cyclists.”

“The material properties of bone and wood are very similar,” says Oyen. “Just because we can make all of our buildings out of concrete and steel doesn’t mean we should. But it will require big change.”



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Waterworld

Flash floods, burst riverbanks, overflowing drains, contaminants leaching into waterways: some of the disruptive, damaging and hazardous consequences of having too much rain. But can cities be designed and adapted to live more flexibly with water – to treat it as friend rather than foe?

In December 2015, Storm Desmond hit the north of the UK. In its wake came floods, the misery of muddy, polluted water surging through homes and the disruption of closed businesses, schools and roads.

Rapid urban growth and progressively unpredictable weather have focused attention on the resilience of cities worldwide not just to extreme events, but also to heavier-than-normal rainstorms, and raised questions as to how flood risk can be managed.

There is of course no ‘one-size-fits-all’ strategy. For some areas, defence is a possibility. For others, retreat is the only option. “But for those unable to do either, we need to fundamentally rewrite the rule book on how we perceive water as a hazard to towns and cities,” says Ed Barsley, PhD student working with Dr Emily So in the Cambridge University Centre for Risk in the Built Environment (CURBE). Barsley believes that adaptation and

planning for resilience can provide a unique opportunity for increasing the quality of towns and cities (see panel).

Dr Dick Fenner from the Department of Engineering agrees that resilience to water should be regarded positively. He is part of the UK-wide Blue-Green Cities project, which is developing strategies to manage urban flood risk in ways that also pay dividends in many other areas, through ‘greening’ the city. “We want to turn rainfall into a win-win-win event,” he says.

When it comes to dealing with floods, one of the major difficulties that many cities face is the impermeability of the built environment. In a city that is paved, concreted and asphalted, surface water can’t soak away quickly and naturally into the earth.

Newcastle city centre, for instance, is around 92% impermeable, and has suffered major flooding in the past. “The ‘flood footprint’ of the 2012 ‘Toon Monsoon’ caused around £129 million in direct damages and £102 million in indirect damages, rippling to economic sectors far beyond the physical location of the event,” says Fenner.

“Traditionally, cities have been built to capture water run-off in gutters and drains, to be piped away. But where is away? And how big would we have to build these pipes if the city can’t cope

“we need to fundamentally rewrite the rule book on how we perceive water as a hazard”

now?” he adds. The principal behind a ‘Blue–Green City’ is to create a more natural water cycle – one in which the city’s water management and its green infrastructure can be brought together.

Cities worldwide are already taking up the concept of ‘greening’, using permeable paving, bioswales (shallow ditches filled with vegetation), street planting, roof gardens and pocket parks. Green infrastructure benefits health and biodiversity, and can help combat rising CO₂ levels, heat island effects, air pollution and noise.

“Not only do they also provide a place for water to soak away,” says Fenner, “they can even create resources from water – such as generating energy from the water flow through sustainable drainage systems and providing places for amenity and recreation.”

“the city’s water management and its green infrastructure can be brought together”

All well and good but with a long list of potential ‘blue–green’ choices, and an equally long list of benefits, how do cities choose the best options?

One of the major outputs of the Blue–Green Cities initiative is a ‘toolbox’ for authorities, planners, businesses and communities to help them decide. Using Newcastle University’s CityCat model, the team assessed how well green infrastructures performed in holding back surface flows, and used novel tracer techniques to follow the movement and trapping of sediments during intense storms. Then they mapped the benefits in a geographic information system (GIS) to identify physical locations that are ‘benefit hotspots’.

The tools were developed by evaluating the performance benefits of green infrastructure gathered from sites in both the UK and USA. As part of a recent 12-month demonstration study in Newcastle, a Learning Action Alliance network was set up with local stakeholders that has, says Fenner, led to new opportunities that reflect the priorities and preferences of communities and local residents.

Now, Newcastle City Council, the Environment Agency, Northumbrian Water, Newcastle University, Arup and Royal Haskoning DHV have combined to be the first organisations in the country

to explicitly commit to a blue–green approach, as recommended by the research. The hope is that other local and national organisations will follow suit.

Embracing resilience, as these organisations are doing, is vitally important when dealing with natural hazards, says Emily So, who leads CURBE: “We should remember that flooding is a natural process and a hazard we need to learn to live with. It is often the disjointed configuration of the built environment that results in it being a risk to the communities. Our aim should be to design to reduce the impact of, and our recovery time from, this natural hazard.”

Fenner adds: “Continuing to deliver an effective and reliable water and wastewater service despite disruptive challenges such as flooding is hard, but vital; it requires continuous and

dramatic innovation. In the future, we will see fully water-sensitive cities, where water management is so good that it’s almost as if the city isn’t there.”

The Blue–Green Cities project is funded by the Engineering and Physical Sciences Research Council (EPSRC), involves researchers from nine UK universities and is led by the University of Nottingham. A parallel project, Clean Water for All, funded by EPSRC and the National Science Foundation, connects the team with researchers in the USA.

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Flood risk as a driver for change

While the Blue–Green Cities project focuses on urban drainage at times of normal to excessive rainfall, Ed Barsley is more concerned with helping communities consider the consequences of extreme events.

“Floods are devastating in their impact and flood risk is often seen as a burden to be endured,” says Barsley, “but future proofing and planning for resilience can and should be used as a driver for increasing the quality of buildings, streets and neighbourhoods – a chance for exciting change in our cities.”

As a case study, Barsley is using the village of Yalding in Kent, which has endured physical, economic and psychological impacts as a result of flooding.

He looked at how each house in the village prepared for and was affected by its most recent flood, its location and building material, and even its millimetre threshold height; and then he looked at future flood risk scenarios. The result is a methodology for assessing resilience that can be used to help inform and plan for adaptation, and is transferable to other communities large or small across the UK and worldwide.

“When we communicated the risks to the community, we found that resilience means different things to different people. Understanding priorities can help them tailor their own strategy to be contextually appropriate,” explains Barsley, who is special advisor on flood risk in the South East to Greg Clark MP, Secretary of State for the Department for Communities and Local Government.

For homes in which resistance measures like flood barriers will be overcome, one option might be to regard the lower floor as a sacrificial space – an area that can be flooded without disrupting waste, power or water. In Yalding, there are examples of homeowners who have done just this and added an extra storey to their homes.

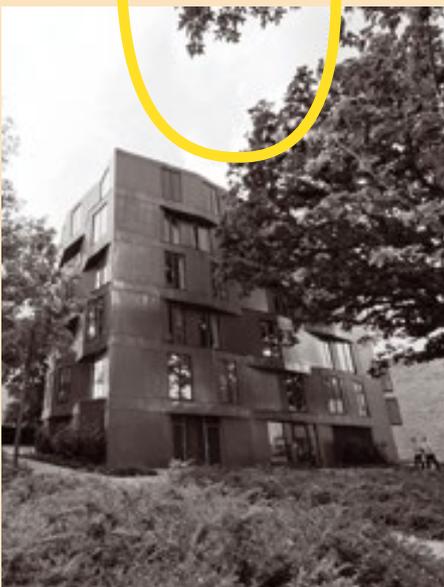
“I’d like to see resilience rewarded and for us to begin to live with water in a different manner. Embedding long-term resilience has huge potential for creating vibrant and enriching spaces.”

www.edbarsley.com

Happy Mondays

(and every day)

“Commuting is a part of everyday life where people could include a bit more physical activity without having to think about it very much or make time for it”



Life in towns and cities can grind you down, but putting health and wellbeing at the centre of new housing and infrastructure developments could make for happier, healthier citizens.

“When a man is tired of London, he is tired of life; for there is in London all that life can afford,” said Samuel Johnson in the 18th century. For Johnson, the rich tapestry of London life and the myriad cultural assets clearly outweighed any downsides of city dwelling.

For others, though, city life is a grind. Public transport is overcrowded, house prices are soaring, traffic is at gridlock and diesel fumes hang almost perceptibly in the air. Little surprise, then, that people do become tired of London, even if not of life itself.

Even if issues such as air pollution are taken out of the equation, living in a city can be bad for your health, which is not good news considering that the World Health Organization estimates that by 2017 the majority of people will be living in urban areas.

A study published in 2014 by Dr Manjinder Sandhu suggested that increasing urbanisation of rural areas in sub-Saharan Africa might lead to an explosion of the incidence of stroke, heart disease and diabetes. Yes, moving to towns and cities provides better access to education, electricity and hospitals, but town and city dwellers become less active, their work becomes less physical and their diets worsen.

“If this pattern is repeated across the globe – which we think it will – then we could face an epidemic of obesity, diabetes and other potentially preventable diseases,” says Sandhu. “Local and national governments need to take this into consideration when planning infrastructure to try and mitigate such negative effects.”

As far as ‘healthy’ cities go, Cambridge has a lot going for it. Its population has higher than average levels of education and is physically active: Cambridge has been nicknamed ‘the cycling capital of Britain’ – the sight of bicycles leaning against walls is as iconic as that of punts passing under the



Image
Accordia – where the provision of more communal than private outdoor space encourages people to interact

Bridge of Sighs. But as the city expands and house prices rocket, more and more people are living in neighbouring villages and towns, where cycling to work along winding, congested country lanes can be less appealing than driving.

In 2011, the world's longest guided busway opened, connecting Cambridge with nearby Huntingdon and St Ives along a former railway line. An integral part of the busway was a cycle path along its route – and this appears to have helped nudge people in the right direction.

A study led by Dr David Ogilvie from the Medical Research Council (MRC) Epidemiology Unit found that, among people who commuted into Cambridge from within a 30 km radius, those who lived closer to the busway were more likely to increase the amount of 'active' commuting they did, particularly cycling.

"Commuting is a part of everyday life where people could include a bit more physical activity without having to think about it very much or make time for it," says Ogilvie. "When new infrastructure integrates opportunities for walking and cycling, we see people shifting their commuting behaviour."

Ogilvie's research is, he says, "contributing bricks of evidence to a wall that's slowly being assembled from across the world of the health benefits of investing into this kind of infrastructure." While such benefits are often alluded to in business cases, until now the evidence to support them has been limited.

There are ways to integrate more pedestrian-friendly environments in existing infrastructure, he says, citing examples such as those in the Netherlands – now being introduced in some areas of London – where traffic is slowed to walking pace and the divisions between pavement and road are deliberately blurred, cuing drivers to share the space.

With more thoughtful urban planning, Ogilvie says, it should be possible to design towns and cities as environments that promote not just physical activity, but improved health and wellbeing – "in short, a place where people want to live".

"Sprawling cities with retail parks on the fringes are not conducive to doing your shopping on foot," he says. "People are more likely to walk and cycle around their neighbourhood if it is safe, well connected and has good local amenities. And getting people out on the streets not only gets them active, it also increases social interactions and a sense that it's safe to be on the streets."

Dr Jamie Anderson from the Department of Architecture is also interested in the relationship between the built environment and our broader

wellbeing. As part of his PhD project with Professor Koen Steemers (Architecture) and Professor Felicia Huppert (Department of Psychology), he did a study of another Cambridge initiative, the housing development known as Accordia.

Since the first residents moved into their homes in the mid-noughties, Accordia has won numerous prizes, including the Royal Institute of British Architects Stirling Prize, for its innovative mixing of private and public spaces. Yet surprisingly, says Anderson, no one had done a detailed study of the impact on its residents.

One of the interesting approaches taken by Accordia was to focus on communal spaces rather than private gardens: only one in five homes has its own garden. Given the stereotype of the British as a very private people, how did people respond? Did people spend time chatting outdoors with their neighbours, or did they shut themselves away and draw the curtains?

The results, explains Anderson, were mixed. While one middle-aged couple missed having their own garden and were now on a long waiting list for a local allotment, one mother described the communal gardens as "crucially important": she had suffered from postnatal depression and, with her husband away at work all day, she told Anderson that she "wouldn't have got through her depression" without the interactions that the adjacent communal areas provided.

"In terms of behaviours that we associate with physical health and positive mental health – so people interacting with each other, children out playing, for example – we found clear positive associations with Accordia's outdoor neighbourhood spaces," he adds, "but when we looked at people's subjective wellbeing, it wasn't as clear cut."

With Accordia, Anderson was evaluating an already established development, but he now has a chance to influence a project at the planning stage. Part of the Chancellor of the Exchequer's vision of a 'Northern Powerhouse' will see a £110 million culture venue in Manchester named The Factory after the eponymous record company behind such iconic bands as Joy Division and Happy Mondays.

Under a fellowship from the Engineering and Physical Sciences Research Council, Anderson, in collaboration with engineering firm BuroHappold, is carrying out a Health Impact Assessment (HIA) of the proposed new site, looking at factors that might influence health and wellbeing,

"the Chancellor of the Exchequer's vision of a 'Northern Powerhouse' will see a £110 million culture venue in Manchester named The Factory after the eponymous record company"

from the lighting in office spaces, through to educational opportunities for young people from deprived communities and the restaurants within the venue.

HIAs are currently voluntary, but are set to become mandatory for significant developments across the UK in 2017, and can help architects and designers improve their submissions for planning application. How effective they'll be is unclear, warns Anderson. "You might have some really strong evidence, but the final decision is a blend of opinion from various stakeholders, so you could end up with a watered-down version of what's needed."

He remains optimistic, however: "We're moving in the right direction. By building consideration of health and wellbeing into the planning process, it should raise the bar and hopefully we will see many more cycle lanes, more inviting and better options for active transport, and maybe fewer fast-food shops."

"I don't know what makes me stay / The city life just ain't the same," sang New Order, one of Factory Record's best known signings, in 2001. Perhaps the work of Cambridge researchers will help make cities attractive – and healthy – places to stay.



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How does your smart city grow?

The Centre for Smart Infrastructure and Construction is building on advances in sensing technology to learn everything possible about a city's infrastructure – its tunnels, roads, bridges, sewers and power supplies – in order to maintain it and optimise its use for the future.

It can be tough getting people excited about infrastructure because we often don't notice it until something goes wrong. We expect to turn on the tap and have clean, drinkable water come out. We expect the underground to work. We expect to flick a switch and have the lights come on.

But just think how different expectations were for people living in Victorian London. The 'Great Stink' in 1858, caused by untreated human and industrial waste flowing directly into the Thames, led to near-constant cholera outbreaks. Eventually, the smell in the Houses of Parliament became so bad that the windows had to be covered with heavy curtains, which goaded the politicians of the day into action. Engineer Joseph Bazalgette came to the rescue by creating a sewer network for central London, which relieved the city from cholera epidemics.

Fast-forward 150 years, and London, and the rest of the UK, is generally in fairly decent shape infrastructure-wise. However, literal and figurative cracks are rapidly appearing. The London Infrastructure Plan 2050, launched in 2014, states that the capital should be able to accommodate its growth, at least until 2025, within existing boundaries, but estimates that £1.3 trillion will need to be invested in the city's infrastructure between 2014 and 2050, an amount more than half of the UK's current GDP.

"Infrastructure, both existing and future, is of paramount importance for supporting economic growth and productivity – and so we must anticipate and plan effectively for the changing needs of society," says Professor Lord Robert Mair of Cambridge's Department of Engineering.

"We can't just build our way out of this – we simply don't have enough space," adds Dr Jennifer Schooling, Director of the Cambridge Centre for Smart Infrastructure and Construction (CSIC). "We have to use the existing infrastructure we've got and get more and more out of it, and when it's appropriate, we can build new infrastructure alongside that."

CSIC, an Innovation and Knowledge Centre jointly funded by the Engineering and Physical Sciences Research Council and Innovate UK, works to bridge the gap between University research and industry in the area of 'smart' infrastructure.

Thanks to technological advances over the past two decades, sensors can now be embedded directly into the fabric of our cities, providing valuable information about the 'health' of a particular road, tunnel, bridge, building,

or any other piece of infrastructure. This information can help identify problems before they become serious, and help get the most out of existing infrastructure, which is particularly important in a small, crowded country like the UK.

CSIC works with different companies and organisations throughout the complex infrastructure supply chain: from owners and operators, designers and builders, to contractors and maintenance personnel, helping them maximise the potential of sensing technology and, by extension, that of the infrastructure we rely on every day.

Since it was founded in 2011, CSIC has built up a network of more than 40 industry partners, including some of the biggest companies in the construction industry, including Laing O'Rourke, Arup and Atkins. It has also worked on some of the largest infrastructure projects in the UK, such as Crossrail and the National Grid power tunnels.

"Infrastructure is of paramount importance for supporting economic growth and productivity"

"Because the construction industry is judged on reliability and safety, it is a conservative one, and so we have to really demonstrate our technologies and approaches, to show that they work," says Schooling. "A conservative industry finds it difficult to grab hold of complex projects, and so we've worked really hard to develop consistent methodologies so that we can train industry to use the technologies we've developed."

One of CSIC's major industry partners, the construction and development company Skanska, has recently established their own company that will make CSIC-developed technology available commercially, after having successfully used it on a project they recently undertook in London. The company was demolishing a 12-storey building to replace it with a 16-storey building in central London, on top of a complex subterranean web of tunnels, transport, foundations, sewers and more.

Skanska worked with CSIC to embed fibre optics in the building pile foundations before it was demolished to determine whether the existing piles could be used again or had to be completely replaced to support the new building. The fibre optic data showed that the foundations did not

have to be completely replaced, as is common practice, which not only saved the company £6 million and six months in added project time, but also won the company a sustainability prize for avoiding pouring the massive amounts of concrete required for completely new piled foundations.

Another CSIC project maximising the value of existing infrastructure is one that is looking to extract the heat from the London Underground to heat and cool the buildings above it. Researchers in Dr Ruchi Choudhary's group in the Department of Engineering are modelling the amount of heat that can be extracted from the Tube, how many buildings can be heated or cooled, and how that might be affected by future climate change. These geothermal systems offer a potential energy-efficient cooling solution compared with energy-intensive conventional cooling.

"A city's infrastructure generates many waste streams: the heat generated in the London Underground is a classic example, leading to severely overheated Tube stations," says Choudhary. "Simulation models allow us to quantify the waste energy that can be usefully harnessed through geothermal boreholes, which makes it possible to demonstrate feasibility and the benefits of operating our infrastructure in more synergistic ways."

"If there's one thing we really excel at in this country, it's making our Victorian infrastructure – such as that designed by Joseph Bazalgette – work well," adds Schooling. "We need to think about the value that infrastructure brings to our cities, which will help us figure out where and when we should be making new investments, and what impact that will have on a city. If we really understand our infrastructure through data, there's a huge opportunity to really make a difference to how our cities perform in the future."

Adds Mair: "Our cities will define the future of society, and smart city infrastructure equipped with modern sensors is essential to achieve the required transformational impact."

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**Image**

For those living in shanty towns and slums, neutral spaces like this makeshift basketball court can offer places of safety in a life of multiple deprivations

Cities exist in a state of constant flux: not always 'smart' and successful, they can be vulnerable, chaotic and seem on the edge of failure. Nowhere is this more apparent than in the shanty towns and slums. How can these informal settlements, and the wider city, be helped to succeed?

Dr Felipe Hernández was born and raised in Cali, Colombia's third biggest city and one of the country's most dangerous – riven by fighting between drug trafficking gangs and the grinding poverty of its shanty towns. One of the most violent neighbourhoods is Potrero Grande along the Cauca River. "When I was a child I never went to the settlements along the bank, although they were only nine or ten miles away. They had a reputation for being dangerous. It took several years and some geographical distance for me to see how deeply divided Cali was then and remains today. As recently as 1997, the city's most prestigious club denied membership to Black people."



Living on the edge

“When I was a child I never went to the settlements along the bank, although they were only nine or ten miles away. They had a reputation for being dangerous”

Various schemes have been initiated to regulate the development of Cali and address the levels of violence in its notorious poorer districts. Although these schemes have commendable objectives, and valuable aspects, they fail to take people’s lived experiences, especially their social networks and productive capacity, into account.

As Hernández says: “Teaching music to poor children is useful because it gets them off the streets. But what happens when they grow up and need to earn a living? How many children have the opportunity to follow a career in music? In a city called Pereira, there was a proposal to train a community in carpentry, but the people who might have benefited have no tradition of working with wood, instead they were farmers.”

Over the past nine years, Hernández, from the Department of Architecture, has concentrated his research efforts on poverty and marginalisation in Latin America. In 2013, he established Cities South of Cancer – a group dedicated to researching the urban environment in the southern hemisphere. Its participants include four PhD candidates in Cambridge, among them Angela Franco, former Pro-Vice Chancellor for Research at Universidad del Valle in Cali, who left her position to undertake research in urban redevelopment supervised by Hernández.

Hernández has looked, in particular, at the expanding informal settlements – slums and shanty towns on the margins of cities – which are home to the disempowered and dispossessed. Where you live plays a large part in shaping your destiny; huge stigma is attached to the terms slum and shanty town. In the course of researching one of the barrios of Medellín in Colombia, for example, Hernández discovered that residents often deny that they live there. Yet it is in these largely unplanned urban settings that millions of people have, for generations, lived, worked and brought up their children. Globally, an estimated one billion people live in slums lacking basic infrastructure, and the United Nations (UN) predicts that this number could rise to three billion by 2050 as cities grow and the numbers of national and international migrants increase.

Informal settlements and the influx of migrants have often been seen as problems to be solved. However, diversity and a flux of people is good for cities, says Dr Wendy Pullan, who leads the Centre for Urban Conflicts Research in the Department of Architecture. “Cities demand diversity. It makes them robust and flexible – places that can thrive and prosper. The question is how to support the activities of communities and encourage social cohesion without losing

the diversity. Planning and architecture have an important role to play in this.”

Hernández agrees: “It seems clear that cities will continue to attract people from rural areas and that pockets of poverty will persist. People who arrive at cities frequently encounter a functioning system to which they are peripheral and from which they are marginalised. Inevitably, there are conflicts between the established population and the new arrivals. And when people from different communities are thrown together in the same slum conditions, the result can be violence.”

“In fact, conflict is as part of the human condition as city building,” adds Pullan, who is working on a book on the nature of urban conflict based on her research funded by the Economic and Social Research Council.

“We have to find better ways of living with the conflict – using and channelling it in a constructive way, rather than thinking we can remove it or banish it,” she says. “The urban topography – the city’s streets and courtyards, roads and rooftops, tower blocks and slums, and all of the activities within them – are as much a part of the problem as they are a part of the solution. When we design cities we need to understand the sociopolitical processes at play and the potential for flashpoints.”

When Hernández and his team looked more closely at the dynamics of Cali, they made an important discovery: “We mapped the invisible boundaries of these areas and we discovered that there were neutral spaces – the church, the school, an adult training centre and sports fields – which sometimes cut across the divides.

“Armed gangs control the neighbourhoods. On Sundays, however, the gang members put down the guns and played football together.”

He suggests that careful planning can capitalise on these safe zones, creating and connecting “corridors of conflict suspension” to form a landscape with the potential for safer mobility.

His team works in partnership with practitioners and researchers in Colombia, Mexico, Indonesia and the USA. One of the central tenets of the project is the concept of articulation. “We use the term ‘articulatory’ to describe a fluid approach to the interaction between the informal economy and the dominant systems,” he says. “In terms of planning and architecture, this approach might mean looking at the ways in which people build their houses and use land, and it also means reflecting on how productive activities can be supported.”

For Hernández, a project undertaken in Querétaro, Mexico, had proved a steep learning curve for their research in Colombia. He explains: “I’d taken a team



Credit: Marcin Gabruk on flickr



Image
Making a living with small
businesses in Medellín, Colombia

“A productive approach is to support the positive activities that thrive in these settlements, and create ways of connecting them to the formal economy”

of undergraduate and PhD students out from Cambridge to work with a Mexican architectural group, Taller Activo. Together, we’d organised workshops in the local community and, with local people, we built three different buildings in the same neighbourhood with the objective of helping to articulate different aspects, and areas, of the community.” One of these buildings – a shared resource with a kitchen – was particularly successful and won first prize in the Servicios y Asistencia Pública category of the 2014 CEMEX Awards.

He believes that academia occupies a privileged position to address the subject of urban programmes that are sustained over long periods and are adaptive to marginalisation. “Universities are vitally important repositories of knowledge and experience, largely unaffected by the pressures to generate revenue that drive private-sector participation.”

Academic research can provide sustained expert advice in the continuous process of building cities. Cities South of Cancer has already generated a substantial body of knowledge on a number of cities in the developing world, and a methodology that could help many others around the world.

Working with local universities in Cali and Bogotá in Colombia, his team produced a map of activities that, although they might operate outside formal structures and not pay taxes, make a

positive contribution to the economy, and have real potential for growth. Research of this kind also questions the conventional categories of employed and unemployed: people who are officially unemployed may well be participating in productive activities outside the formal economy.

One example that Hernández gives for Cali is sand extraction, an activity that provides a living for large numbers of people. Communities living on the Cauca River have built machines to extract sand that is transported to construction sites – where it enters the formal economy. These same people have established dwellings and businesses on a flood plain where there is danger of inundation. Because they have built sturdy houses (concrete and brick), often on stilts, drowning accidents are rare. Not surprisingly, the owners of these houses and businesses don’t want to be moved away from the river as they would be separated from their workplaces and their long-standing community.

On the periphery of Cali, people living along the Cauca River, in District 21, keep cows, pigs and goats for milk and meat. At present, meat from this area enters the market surreptitiously, and waste is disposed haphazardly into the river. Hernández argues that, because these activities have established social structures, they could be developed relatively easily: quality controls could be established and the environmental footprint could be reduced, maximising benefits for the local communities and the city at large.

Similarly, animals and plantations kept by people along the riverbank also present an opportunity. The entire seven-mile riverbank could be transformed into a productive linear park, thus recuperating the river for the city. He says: “A park of this kind could be a place where children go to become more involved in the production of food and learn about rearing animals. Instead of maintaining current socioeconomic divisions, this form of urban articulation would bring two ‘distant’ communities together, contributing to the search for peace.”

Here, there is a subtle emphasis on building the ‘urban commons’ – areas

“There is a need for international policy on poverty reduction to stop romanticising slums”

of collective ownership and resource management – in ways that benefit the poor, signalling an approach to slums that is neither about gutsy survivalism nor about handouts. This approach is developed by Professor Ash Amin, from the Department of Geography, in his new book with Professor Sir Nigel Thrift, *Seeing Like a City* (Polity 2016).

Currently, argues Amin, slums and informal settlements tend to get narrated either as uncongenial spaces where people on very low incomes face multiple deprivations – ill health, insecurity, violence and harassment – or as spaces of hardship negotiated successfully by enterprising residents and entrepreneurial capability, from where the rural poor may begin their journey towards becoming middle class.

Slowly, however, argues Amin, “a new language of facilitation is being used by institutions like UN-Habitat, who seek to identify how the poor can be enabled to participate in and derive benefit from the urban growth machine of the larger city. This might be through improving access to goods and services, jobs and opportunities, information and knowledge, or skills and capabilities.”

Amin thinks that this language of facilitation should be pushed much further than the current policy emphasis on harnessing the capabilities of the poor as a way of dealing with the challenges of slum living and debilitating informality.

“There is a need for international policy on poverty reduction to stop romanticising slums – countering the hyperbole of blockbuster films like *Slumdog Millionaire* – and to get behind the ‘capabilities’ of the poor in underserved cities left to fend for themselves,” says Amin. “What this means is offering the poor a set of infrastructural rights of access to the staples of the urban commons – water, electricity, basic health care and education, sanitation, and the like – along with rights to basic income, so that the ground for the more active participation of marginalised communities in city life can be prepared on a sustainable basis.”

In this way, slums (and those who dwell in them) can be seen by governments and policymakers as ‘enabled’ spaces – much

in the same way as cities are offered to elites and middle classes. Neither neglected nor swept away in wholesale clearances, but upgraded in ways that allow collective life to flourish at low cost and with considerable gains, according to Amin.

Hernández argues that the formal and informal economies are not separate entities but meshed together – and that this fluidity represents an opportunity. He says that a more productive approach is to support the positive activities that thrive in these settlements, and to create ways of connecting them to the formal economy.

Slums might not exist in the developed world on the same scale as in the developing world but interaction between formal and informal activities applies as much in London or New York as in Bogota. “We’re talking about the same key issue,” explains Hernández, “of people finding ways to make a living however they can.”

“It is the weaving together in cities of humans, technologies and infrastructures that gives cities their world-making power,” adds Amin. “In past cities, leaders have understood this collective agency; contemporary policymakers need to return to the question of how the material and human interdependencies that constitute urban provisioning systems can be harnessed for the many and not just the few. The city is brim full of opportunity when it is organised as a commons.”



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NUUDGE

NUUDGE

From wind turbines and solar photovoltaics to grey water recycling and electric vehicles, technology is making it ever easier for us to be green – yet many of us are not. Now, Cambridge researchers are discovering that our personalities and communities have a major impact on our environmental decisions, opening up new ways to ‘nudge’ us into saving energy and carbon.

For those of us who pay fuel bills, saving energy by insulating our homes or perhaps installing solar panels seems to make perfect sense. It saves money, therefore as rational human beings why don’t we all do it?

It’s a question that preoccupies Dr Franz Fuerst from the Department of Land Economy. “If you just follow the bottom line, you should see a lot more investment in energy efficiency purely from a profit-maximising perspective. And we should see even more if we take the costs of climate change into account. Why it’s not happening is a puzzle that keeps me awake at night,” he admits.

Fascinated to find the factors at play, Fuerst and his colleague Ante Basic-Sontic started supplementing their economic models with insights derived from psychology.

According to their newly developed theoretical framework, our personalities – as described by the ‘Big Five’ personality traits of Openness, Conscientiousness, Extraversion, Agreeableness and Neuroticism – have a major influence on our decisions about investing in energy efficiency because of the way they relate to our attitudes to risk and the environment.

To provide evidence for the theory, they analysed data from the Understanding Society survey (previously called the British Household Panel Survey), which since 2009 has surveyed some 50,000 households and 100,000 individuals every year. “It’s a rich data set that captures all possible indicators for a household, including energy efficiency decisions and attitudes as well as personality traits,” says Fuerst.

They found that personality traits matter in terms of investment decisions in energy efficiency, even when controlled for drivers such as income, gender and education, although some personality traits are more strongly associated with investment decisions than others.

“Making any investment is almost always a risky undertaking. This is particularly true for many energy efficiency investments that require upfront capital expenditure while the actual energy savings and payback

periods occur at a later time, which introduces risk. But what is considered an acceptable level of risk differs widely across people and households.”

This makes attitudes toward risk an interesting factor to consider when explaining energy efficiency investment decisions. “Openness, which is generally related to lower risk aversion, has a distinct impact on investment behaviour and is our strongest trait,” he explains. “Neuroticism and Agreeableness lead people to be more risk averse, while Extraversion has a positive association with risk. Conscientiousness instead shows only a weak impact on investment behaviour through the risk channel.”

They also found sizeable differences between personality traits and environmental attitudes and the same personality traits and actual investment outcomes. “We find that with rising income, personality traits become more important as factors that determine green investment. Your personality traits don’t get a chance to manifest themselves if you lack the money to invest.”

Given policymakers’ limited success in encouraging more of us to invest in energy efficiency, understanding how personality affects these decisions could help us develop more effective policies and incentives, Fuerst believes.

“Because perceived risk and risk aversion are the two key mediating factors, there is scope for developing more bespoke financial products that are attractive if you have a very low appetite for risk.”

There is already a range of financing options available that involve transferring some or all of the investment risk from the property owner to a private or public sector third party but these are currently focused on larger organisations and businesses and have yet to be rolled out to households on a large scale. Additionally, information campaigns can help to increase the awareness among the risk averse that the ‘do nothing’ option is by no means risk-free and might in fact be the riskiest choice. “For example, via the larger exposure to future energy prices, tightening regulations or a potential drop in market value for properties with poor energy efficiency,” he says.

For those of us who pay fuel bills, saving energy by insulating our homes or perhaps installing solar panels seems to make perfect sense... why don't we all do it?

Environmental decisions, are affected not just by personality and attitudes to risk, but also by urban design and social conditions – factors that Professor Doug Crawford-Brown and PhD student Rosalyn Old are exploring.

“Cities are increasingly incorporating sustainability metrics in the way buildings are built, the materials and resources used by occupants, and how waste is disposed of,” Crawford-Brown explains. “But how can we ensure cities will meet these metrics and perform sustainably? One of the most important challenges is to understand how people are motivated to act sustainably, and how those motivations are stimulated by the design and operations of communities.”

To understand more about the take up and use of green technologies, Old is studying the University’s North West Cambridge (NWC) Development, an extension to the city that is currently being built. “House builders are under pressure to include green technologies in new buildings, yet the take up and use of these technologies is uncertain,” she says. “This is a good opportunity to

look at what’s special about NWC, how energy and carbon can be saved in a development like this, and learn lessons that can be transferred to future sites.”

Taking a range of technologies – from solar panels and water recycling to the district heating system and electric car charging points – that are being built into NWC, Old is modelling which technologies will be most efficient according to how people behave.

Residents have yet to move into NWC, so she is surveying equivalent demographic groups in Cambridge, such as postgraduates, key workers and families, to find out about their values, norms and attitudes so that she can model how they are likely to use the green technologies on offer.

“We can look at the energy impact given certain scenarios,” she explains. “For example, if 50% of postgraduates are ‘keen greens’ and they all cycle to their departments, the model will tell us the energy impact.”

And because the model includes the ability to interrogate different scenarios, it allows project managers to calculate the carbon savings associated with encouraging certain groups to be more environmentally conscious, opening up new ways of nudging residents to be greener.

Old hopes the model will help shape future phases of NWC, as well as other sustainable city sites and other sectors: “What we discover about how to shift people between different behavioural groups is important and can be used in policy work in many sectors. Even small changes in urban design can make a big difference.”

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Smart city, MAGIC city

Nudging people to make sustainable lifestyle choices is one thing, but can a city be nudged towards energy-efficient investments, lower emissions and cleaner air?

Cities cope with pollution and uncomfortable temperatures by closing windows and installing units that heat, ventilate and air condition, which themselves guzzle energy and frustrate efforts to decarbonise.

A new interdisciplinary research project aims to halt this unsustainable trend by creating solutions that make cities cleaner with minimum use of energy. The key to progress, says project leader Professor Paul Linden, in the Department of Applied Mathematics and Theoretical Physics, is to start treating the city as a complete, integrated system.

“Experience over the past two decades suggests that when infrastructure investment works closely with innovative urban design across a city, there’s a shift towards low emissions and lower carbon travel through spontaneous citizen choices,” he explains.

The £4.1 million Managing Air for Clean Inner Cities (MAGIC) project will link data fed from sensors monitoring a city’s air to an understanding of air flow inside and outside buildings, and innovations in natural ventilation processes. The idea is to develop an integrated suite of models to manage air quality and temperature (and, consequently, energy, carbon, health and wellbeing) – at the level of buildings, blocks and across the whole city.

To do so, engineers, chemists, mathematicians, architects and geographers from 12 university and industry organisations will be working together, with funding from the Engineering and Physical Sciences Research Council.

The model and associated decision support system will, for example, provide information on how traffic routes can be optimised to reduce pollution, and the cost-benefits of introducing cycling routes and green spaces. But the main value of understanding energy use and air flow, says Linden, is that a city can monitor itself continuously – it can, in effect, become its own natural air conditioner.

www.magic-air.uk

Extreme sleepover: Living beside Uruguay's 'Mother Dump'

Patrick O'Hare describes his time with the *clasificadores* – the families who scour Montevideo's pungent 'wastescape' to recover and classify anything that is valuable, usable or edible.

Returning to Uruguay's largest landfill (cantera), 'Felipe Cardoso' in Montevideo, to conduct fieldwork for my PhD, I was delighted when local social worker and missionary Jorge told me that I could live at his home, in a housing co-operative overlooking the landfill.

I had worked as a labourer in the construction of the co-operative in 2010 and knew that most of the occupants were relocated residents of an infamous shanty town built on top of an old landfill.

I could use the house as a base for exploring Montevideo's formal and informal waste trade, since many neighbours were urban recyclers, known locally as *clasificadores* or classifiers. I'd be able to accompany them as they left in the morning to recover value from the trash at sites nearby, often returning in the afternoon on motorbikes, trucks or horse-drawn carts laden with an impressive array of plastics, metals and cardboard, as well as food, clothing and electronics for domestic consumption or neighbourhood sale.

Waiting to move in and impatient to start fieldwork, I had eagerly accepted when one neighbour offered to host me temporarily in his yard. As it transpired, I lived for a week in the most densely populated accommodation I have ever experienced. Now, though, Jorge's house would be my home for the following year. Initially it was a concrete block lacking windows and doors, but I set about making it habitable, mostly using materials scavenged from the landfill.

Of course I could do nothing about the sights, sounds and smells of the landfill itself. It rose over the horizon, the third highest peak of low-lying Montevideo; the beeping of its reversing compacters could be heard throughout the night; and the strangely sweet smell of mixed urban rubbish drifted over in the morning mist.

Each day, some 60 trucks roll into the compound filled with urban rubbish. At the last count (in 2008, and likely to be an underestimate), around 5,000 waste-picking families were making a living from Montevideo's trash, attempting



Credit: Patrick O'Hare

to recover all that is valuable, usable or edible. Their role in a city where waste management has reached crisis points in the past has been lauded as a lesson to society: they help to reduce the environmental and financial cost of landfill and find value in something that might be surplus to some but not others.

Like my interlocutors who recovered materials from there, I had ambivalent feelings about the cantera which, because of its reliable provision, was nicknamed "the mother". On the one hand, it was an intriguing site for fieldwork where, under the supervision of Dr Sian Lazar, I focused on the processes of labour formalisation, the sociocultural dynamics of the waste and recycling work, and the history of waste infrastructure and aesthetics. On the other hand, it was also a place of hazard, police violence and a smell that lingered on clothes and skin, getting into hair and under fingernails.

I never slept at the dump but this was previously a common practice: *clasificadores* would camp there for days or weeks at a time, always at the mercy of the feared mounted

police, who would set tents alight, showing little tolerance for intruders.

The closest I came to the apparently boisterous atmosphere of these encampments was joining *clasificadores* of the Felipe Cardoso recycling co-operative as they spent the last nights in a building the municipality had ceded them for facilities but which some had appropriated as a residence. With the exception of veteran worker Coco, who lived there permanently, the space seemed to function as a temporary refuge for male *clasificadores* who had been kicked out by their wives! On the night of my visit, we sat and played cards, listened to cumbia music, drank into my supplies of Scotch, and discussed the impending closure of the site and the workers' relocation to a formal sector recycling plant.

With the municipal government's attempted formalisation of Montevideo's recycling trade, it is possible that the days of such precarious, autonomous, *clasificador* spaces are numbered, to be replaced by hygienic and technologically provisioned infrastructures. Yet at the end of my research trip, many

“it was a place of hazard, police violence and a smell that lingered on clothes and skin, getting into hair and under fingernails”

of my neighbours were still making their way to the cantera to classify the tons of waste dumped there daily.

Uruguayan priest Padre Cacho once described clasificadores as “ecological prophets” and I can see what he meant – they have long functioned as ‘prospectors’, mining the urban waste stream for valuable materials that consumers have been happy to discard, and municipal governments send to landfill or incinerate.

Now back in Cambridge as an intern at the Centre for Science and Policy (CSaP), I am helping to organise a workshop on the ‘circular economy’ to explore the ways that government and industry are increasingly reconceptualising waste as a recoverable resource. At a global level, it is important that shifts in policy benefit rather than dispossess informal sector recyclers, the long-time ‘artisanal miners’ of the waste stream.

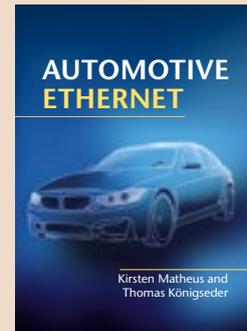
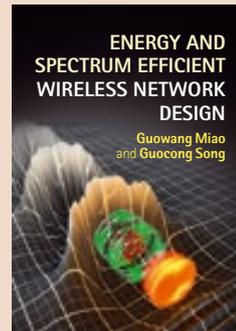
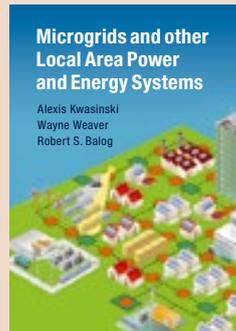
Just before leaving Montevideo, the annual landfill clasificador Christmas social afforded me an enduring image of slumber amidst the scraps: an old, intoxicated and weary recycler lying on a recovered floral mattress, his sweated brow resting on a large folded rubbish bag, surrounded by thousands of pesos worth of scrap metal.

Patrick’s policy internship at CSaP is funded by the Economic and Social Research Council Cambridge Doctoral Training Centre.

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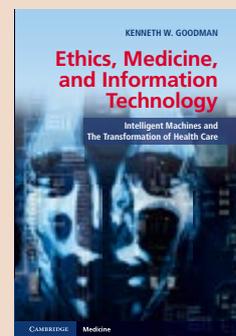
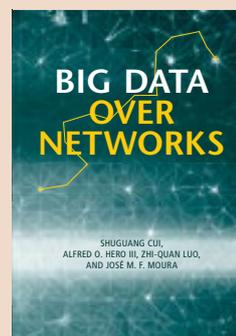
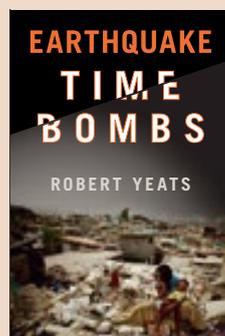


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Cover

Flooding can be a misery and an economic nightmare, but it's also a natural hazard. Can we design and adapt cities to live more flexibly with water – to treat it as friend rather than foe? Find out more on p. 26 this issue, as part of our focus on the future of cities.

