

Research

Horizons

Pioneering research from the University of Cambridge



Issue 37

Spotlight
Children

Feature
Earth-like planets

Feature
**Quantum
communication**



**UNIVERSITY OF
CAMBRIDGE**

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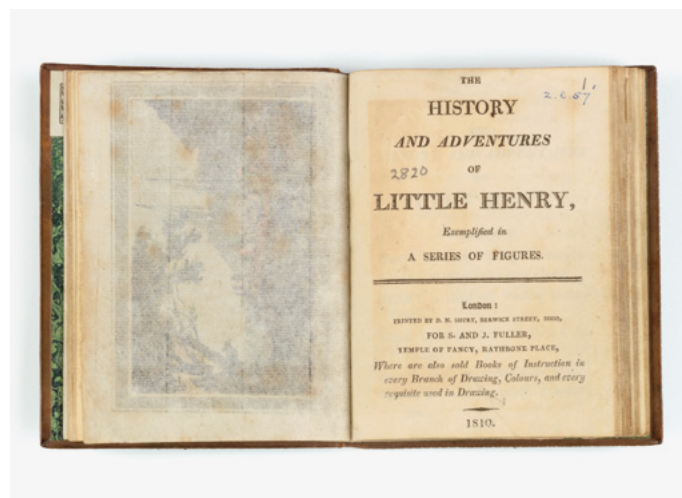
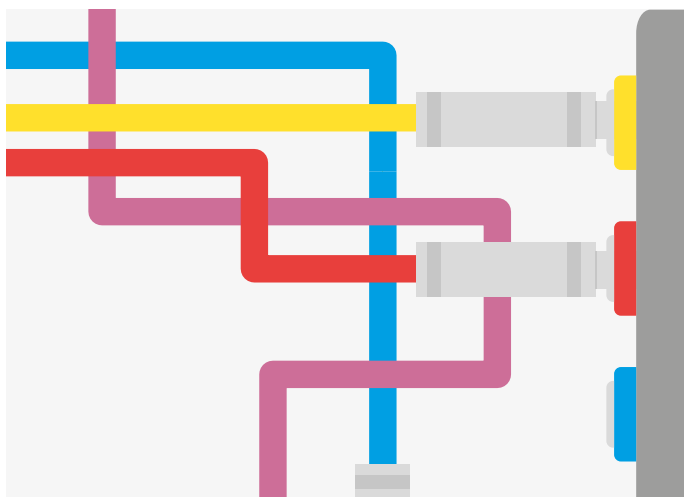
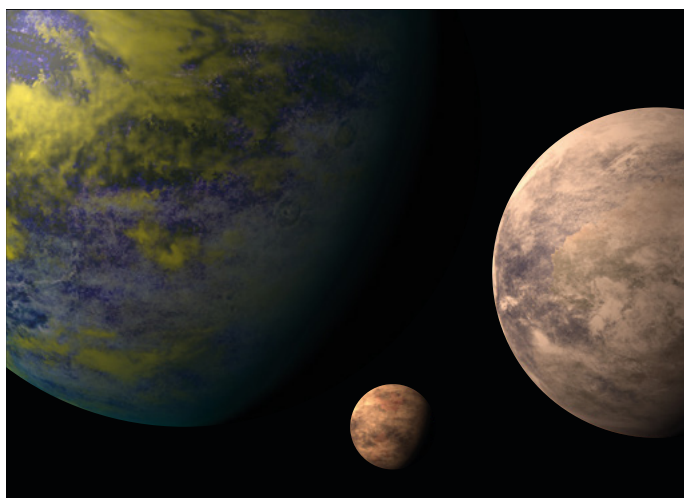
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Welcome

Our front cover shows the hand of a child filled with paintings by children at the University of Cambridge Primary School. Their artwork symbolises the spirit of the School to be open and alive to the possibilities inherent in every child – sentiments that run through the articles in this issue's Spotlight on children.

We hear how our researchers are probing deeply into the role of parenting and education in early life, as well as how the Primary School – which is sponsored by the University to provide education for the local community in North West Cambridge – is putting the very best of research into the very best of teaching. This summer, it received a rating of 'Outstanding' by Ofsted.

We also hear about studies aimed at understanding the vulnerabilities of the developing brain, including why some teenagers are especially at risk of developing mental health disorders. The work highlights the importance of early identification and treatment.

It is abundantly clear how important it is that we support children to grow into healthy, happy and inquiring adults, and yet we live in a world where it is estimated that up to one billion young people worldwide are victims of violence each year. One question our researchers are asking is how such adverse experiences shape a person's lifelong development.

Our research is also having unexpected effects – such as a book of 'lost words' that encourages children to love and protect the natural world and which, thanks to crowdfunding campaigns, is appearing in primary schools across the UK.

Elsewhere in the issue, we learn about a sustainable food source based on maggots, the cryptographic skills needed to decipher manuscripts and the next generation of batteries that could power a green revolution. We search for other Earths, witness shamanic rituals and hide 'unhackable' encryption keys inside particles of light. We also meet a political scientist who shares how she has turned her childhood experiences in Rwanda into a desire to make a contribution to peace.

We hope you enjoy this edition of *Research Horizons*.

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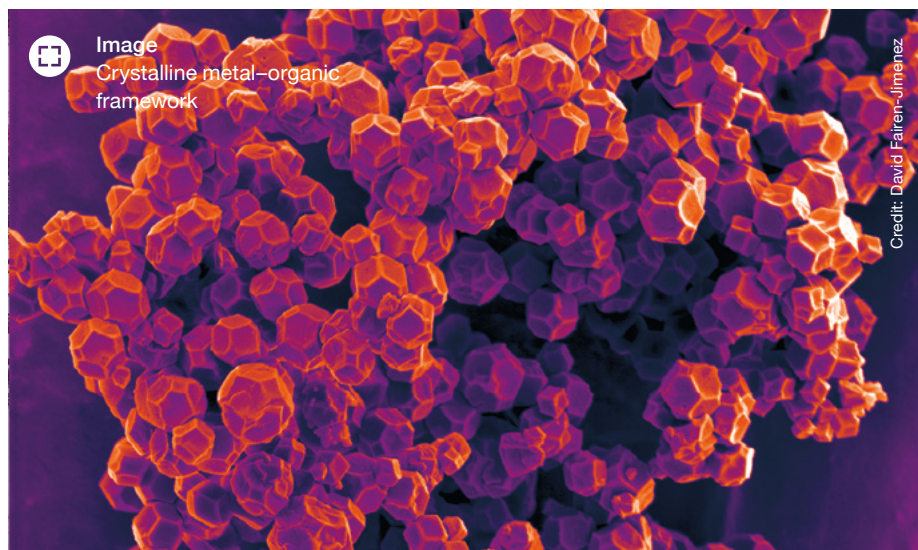
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News



Targeting hard-to-treat cancers

Cambridge leads a £10 million interdisciplinary collaboration to target the most challenging of cancers.

While the survival rate for most cancers has doubled over the past 40 years, some cancers such as those of the pancreas, brain, lung and oesophagus still have low survival rates.

Such cancers are now the target of an Interdisciplinary Research Collaboration (IRC) led by the University of Cambridge and involving researchers from Imperial College London, University College London and the Universities of Glasgow and Birmingham.

“Some cancers are difficult to remove by surgery and highly invasive, and they are also hard to treat because drugs often cannot reach them at high enough concentration,” explains George Malliaras, Prince Philip Professor of Technology in Cambridge’s Department of Engineering, who leads the IRC. “Pancreatic tumour cells, for instance, are protected by dense stromal tissue, and tumours of the central nervous system by the blood-brain barrier.”

The aim of the project, which is funded for six years by the Engineering and Physical Sciences Research Council, is to develop an array of new delivery technologies that can deliver almost any drug to any tumour in a large enough concentration to kill the cancerous cells.

Chemists, engineers, material scientists and pharmacologists will focus on developing particles, injectable gels and implantable devices to deliver the drugs. Cancer scientists and clinicians from the Cancer Research UK Cambridge Centre and partner sites will devise and carry out clinical trials. Experts in innovative manufacturing technologies will ensure the devices are able to be manufactured and robust enough to withstand surgical manipulation.

One technology the team will examine is the ability of advanced materials to self-assemble and entrap drugs inside metal-organic frameworks. These structures can carry enormous amounts of drugs, and be tuned both to target the tumour and to release the drug at an optimal rate.

“We are going to pierce through the body’s natural barriers,” says Malliaras, “and deliver anti-cancer drugs to the heart of the tumour.”

GPS in the playground

Wireless tracking technology is offering a new way to explore children’s social behaviour at playtime.

Research by Dr Jenny Gibson at the Faculty of Education has pioneered the use of specially designed satellite-linked trackers attached to children’s baseball caps to understand how they interact in the playground.

The sensors were tested with a class of children aged seven to eight during ten typical playtimes, and then ten more sessions in which large play materials such as nets, tarpaulins and blocks were made available.

The research team, from Cambridge and University College London, was able to collect data showing how children moved and interacted under different circumstances, establishing that wearable technology offers an effective new way to examine play behaviour – traditionally analysed through observation.

“This is a small-scale study but we have seen that the technology works and has got a lot of potential,” says Gibson, a researcher at the Centre for Research on Play in Education, Development and Learning. “School playgrounds are significant spaces in children’s lives, but their importance for social, physical and cognitive development is under-researched and poorly understood.”

The satellite-linked trackers showed the position of each child at a series of time points. Combined with video of the playtimes, the data allowed researchers to identify how different movement patterns are associated with different types of play, and to easily quantify the varying levels of social interaction among the children.



News in brief

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

03.10.18

Sir Greg Winter is jointly awarded the 2018 Nobel Prize in Chemistry with two others for the phage display of peptides and antibodies.

14.09.18

Researchers find that ‘high-yield’ farming costs the environment less than previously thought – and could help spare habitats.

Arts and humanities doctoral training

Almost 400 new doctoral places will be created by the Open-Oxford-Cambridge partnership.

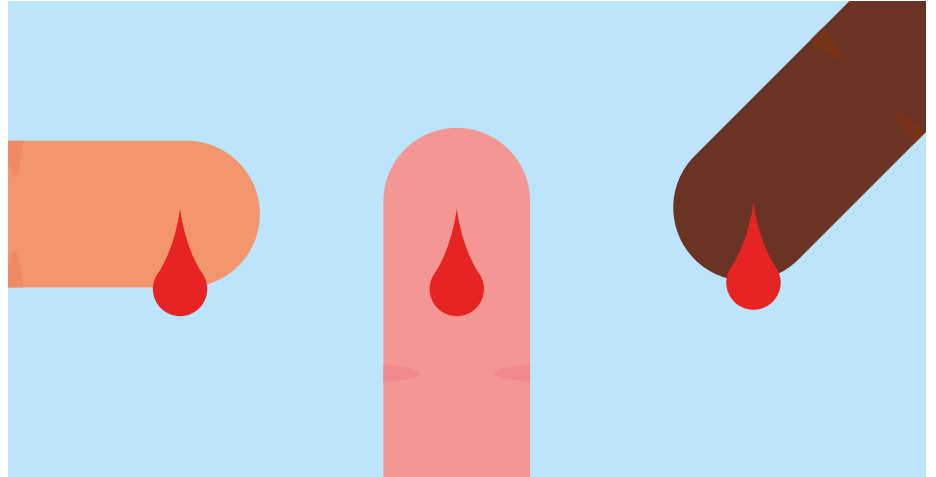
The Open University, the University of Oxford and the University of Cambridge have joined forces to launch a Doctoral Training Partnership (DTP) with funding from the Arts and Humanities Research Council (AHRC) and supported by partnerships with the BBC World Service, the National Trust and British Telecom.

“The DTP will offer students a wealth of opportunities to pursue research and engage in training, and to learn from each other as part of a large multidisciplinary group,” said the DTP’s incoming Director, Professor David Rechter. “These opportunities will equip our DTP students with the research expertise and skills that will allow them to go on to a wide range of careers in academia and beyond.”

The funding is part of the AHRC’s substantial commitment to funding doctoral research, with investment in ten DTP consortia bringing together 72 UK higher education institutions that will receive more than £170 million in funding over eight years.

The AHRC’s Director of Research, Strategy and Innovation, Professor Edward Harcourt, said: “Our support for the next generation of arts and humanities researchers is critical to securing the future of the UK arts and humanities sector, which accounts for nearly a third of all UK academic staff, is renowned the world over for its outstanding quality and which plays a vital part in our higher education ecosystem as a whole.”

Professor Martin Millett, Head of Cambridge’s School of Arts and Humanities, added: “The unique collaboration between Oxford, Cambridge and the Open University opens up exciting new prospects for the next generation of doctoral research students in the arts and humanities.”



Kalium Diagnostics

A simple home finger-prick test could help kidney patients check their potassium levels are not dangerously high or low.

Our kidneys keep salts and minerals in balance in the body. Abnormally high or low levels of potassium are particularly dangerous and can be fatal, so patients with kidney disorders have to have their levels regularly checked at the hospital or GP surgery.

A University of Cambridge spin-out company, Kalium Diagnostics, is now developing a simple finger-prick test for patients to monitor blood potassium levels instantly in their own home. The company was recently named Cambridge’s Best Healthcare Start-Up in the AstraZeneca Start-Up Science competition.

“Patients were asking me why they couldn’t monitor their own blood potassium levels in the same way that people with diabetes monitor their blood sugars, and the idea for a home test was raised via Addenbrooke’s Hospital’s Patient-Led Research Hub,” says Professor Fiona Karet, from the Cambridge Institute for Medical Research and Honorary Consultant in Renal Medicine at the hospital.

When Karet met Dr Tanya Hutter, an expert at building miniature sensors, the idea began to become a reality.

“The technology is based on an electrical signal,” says Hutter, from the Department of Chemistry. “This allows the sensors to be low cost and disposable, as well as miniature enough to measure potassium in a tiny drop of blood.”

Proof of concept was developed by the researchers with funding from Kidney Research UK, Addenbrooke’s Charitable Trust and Addenbrooke’s Kidney Patients’ Association, and commercialisation was helped by Cambridge i-Teams and the Cambridge Judge Business School. Dr Liz Norgett, a research associate, has been doing most of the lab work.

Kalium Diagnostics was also one of the winners of Accelerate@Babraham. With business mentoring plus lab space at AstraZeneca and Babraham Research Park, the team is now working towards sensor manufacturing and clinical trials.

“Patients know their own disease needs and it’s exciting to think that we’ve been able to respond in this way,” says Karet. “It can also be used by other patient groups and healthcare professionals. If patients can better manage their health away from hospital, it will improve their lifestyle and reduce the costs of healthcare.”

www.kaliumdiagnostics.com

01.08.18

Professor Caucher Birkar is named one of four recipients of the 2018 Fields Medal, one of the most prestigious awards in mathematics.

26.07.18

Historian uncovers new evidence of how 18th-century London supported its unmarried mothers and illegitimate children.

24.07.18

Cambridge to appoint a DeepMind Chair of Machine Learning, thanks to a benefaction from the world-leading British AI company.

On the steppes of Mongolia and in its capital city Ulaanbaatar, social anthropologist Dr Elizabeth Turk explores why the religion of shamanism is booming.

Buyankhishig crisscrossed the hillside before making offerings of vodka and milk. Then, beating her drum and chanting, she invited her ancestral spirits to enter her body.

Several times a year, the shamanic healer visits her rural homeland to rejuvenate her shamanic practice in this way. The trip offers a break from her challenging yet rewarding work in the peri-urban districts of Ulaanbaatar, where neighbours visit to share their problems – illness, domestic violence, financial worries – and receive her advice.

Largely considered by Mongolians as a pre-Soviet ‘tradition’, shamanism has gained popularity over the past 30 years. “Shamanism plays an important role in national cultural imagination,” says Dr Elizabeth Turk, who is exploring the increase in nature-based remedies and alternative medicine in the wake of the country’s seismic politico-economic shifts of recent decades.

“Mineral mining, pollution and mass migration to the capital have coincided with local perceptions of an increasing volatility of ‘spiritual masters’ of the landscape. The causes of certain illnesses are attributed to retribution from these entities,” she says.

Some shamans are vocal in protest, struggling against foreign mining companies to defend nature. Others, including Buyankhishig, are more ambivalent. She worries about the destruction of the landscape, but her nephew works in the local mine – a job that brings regular income for his family.

“The importance of maintaining a relationship with the natural world, especially as that relationship changes, is widely held by shamanists and non-shamanists alike,” says Turk. “A common understanding is not necessarily that mining should stop but that it needs to be done the right way, by restoring the natural environment.

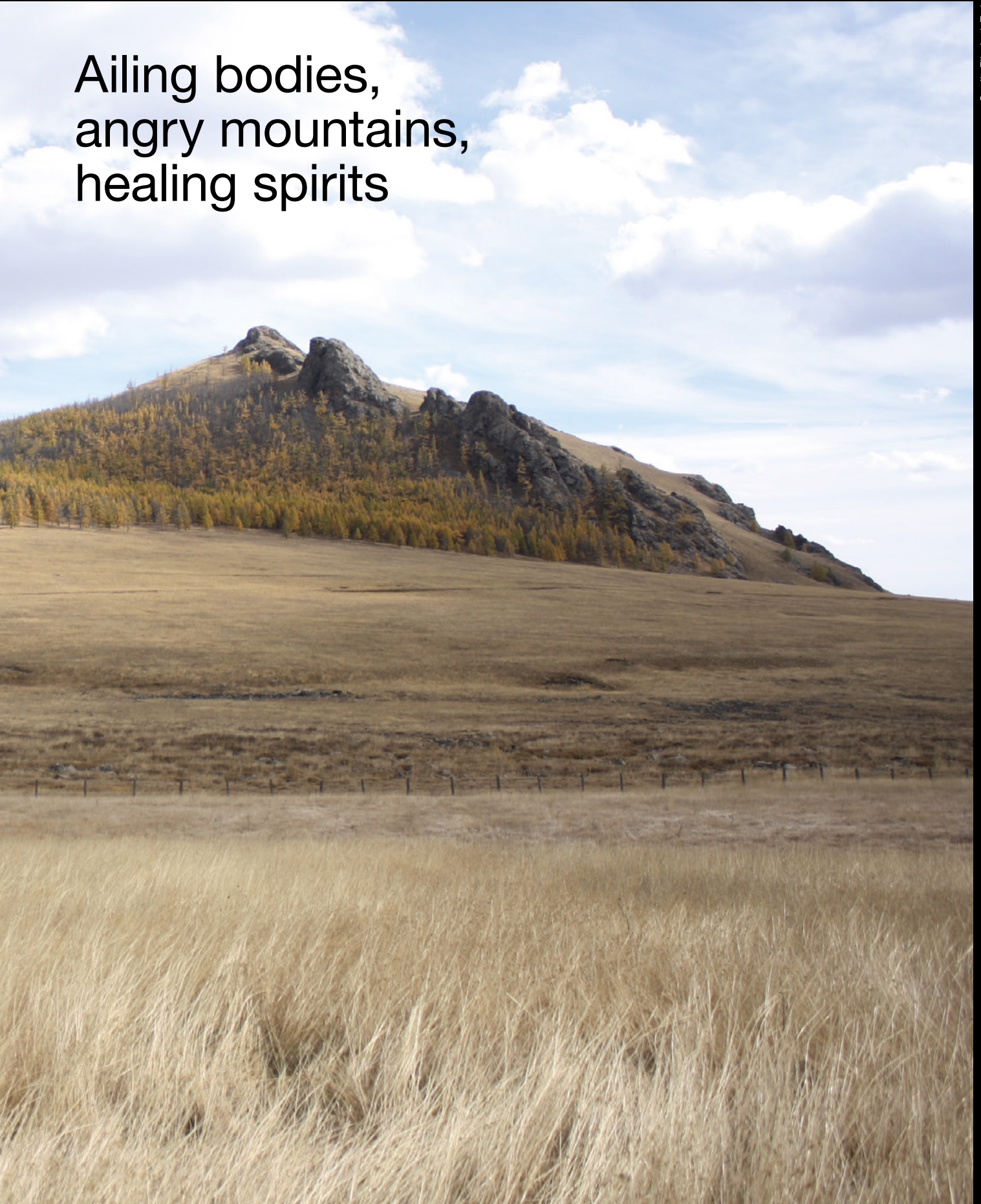
“My research asks what are the implications of a global need for minerals for the people who live in the places rich in them?” says Turk. “Tracing these tensions and ambivalences locally affords unique insight into global systems that affect us all.”

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Words
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Ailing bodies, angry mountains, healing spirits



Q U A N T U M

Cambridge researchers are devising new methods to keep sensitive information out of the hands of hackers. They launched the UK's first 'unhackable' network – made safe by the "laws of physics" – earlier this year.

When buying an item online, we voluntarily hand over our credit card information. But how do we know that it's safe? Most sensitive information sent over the internet is secured through encryption, a process that converts information into a code that can only be unlocked by those with the encryption key. Currently, encryption keys are essentially impossible to break with conventional computing equipment – it would simply take too long and too much computing power to do the mathematical calculations that could reveal the key.

But in the coming decades, all that could change. Google, IBM and many other companies are all working to build a quantum computer that would outperform contemporary computers by taking advantage of the ability of subatomic particles to exist in more than one state at a time. A quantum computer could enable us to make calculations and solve problems that are well out of reach of even

the most powerful supercomputers, but in the wrong hands they could also crack encryption keys with relative ease.

So how can individuals, corporations and governments keep information safe in the face of this potential threat?

A group of researchers in Cambridge's Department of Engineering are working to defend against the security threats posed by quantum computers by developing 'unhackable' encryption keys hidden inside particles of light, or photons, and sent over optical fibres.

Quantum keys are generated randomly through quantum mechanics, taking advantage of a property of photons that prevents them being cloned. The real strength of quantum links, however, is that if an attacker attempts to intercept the key, the quantum state of the photons changes and they cannot be used as part of the key, rendering the information carried by the stolen photons worthless.

"This means that we can send single photons over our networks and end up with keys at each end which are fundamentally secure," says Professor Ian White, Head of the Photonics group in Cambridge's Department of Engineering.

In June 2018, White and his colleagues Professor Richard Penty and Dr Adrian

Wonfor started putting these ideas into practice with the launch of the UK's first quantum network. The 'metro' network provides secure quantum communications between the University's Electrical Engineering Division in West Cambridge, the city centre and Toshiba Research Europe Ltd (TREL) on the Cambridge Science Park. It was built with corporate partners including ADVA and Toshiba.

The network has since been extended and connected to other sites around the country, including BT's research and development centre in Ipswich, and is currently being extended to the National Physical Laboratory in London and the University of Bristol, creating the first UK quantum network.

The quantum network is a project of the Quantum Communications Hub, a consortium of eight UK universities led by the University of York, as well as private sector companies and public sector stakeholders. It's funded by the Engineering and Physical Sciences Research Council (EPSRC) through the UK's National Quantum Technologies Programme.

"This network provides us with a UK facility where we can test ideas that until now have been research based, and to get users used to the concepts behind

developing 'unhackable' encryption keys hidden inside particles of light sent over optical fibres

quantum communications so they can translate this technology into practice,” says Penty. “There’s a world of difference between transmitting quantum keys over a coil of fibre in the lab and actually putting it in the ground.”

The network has the highest quantum key rate in the world. This secures a data network in Cambridge that runs at roughly five times the capacity of the entire University network, and the link to BT in Ipswich operates at five times that again. The link to BT is comparable with the highest data capacity links in the UK, and has the possibility for scale up in future.

“For us, it’s really important to get this right as it’s our first chance to start doing very detailed studies and see how these systems really work in the field,” says White. “This is only the start, however.”

In addition to the continued growth and development of the quantum network, the researchers are also investigating other ways that quantum technology could be used to secure information. For example, instead of counting individual photons, it could be possible to measure the amplitude and phase properties of pulses. “This way, you could use a type of hardware that’s not so different from conventional networks, so it would dramatically reduce the cost,” says Wonfor. “In theory, this would represent a huge step towards commercialising quantum technology, because it would effectively rely on technology that people are already used to.”

The researchers are also looking at turning the entire concept on its head, and

instead of relying on quantum mechanics for encryption key distribution, it could be used as a type of quantum alarm. In this scenario, the quantum signal would be in the background, buried inside a classical data signal, and would detect when an intruder attempts to break into the fibre.

“At the moment, it’s not easy to detect whether someone is tapping into the actual fibre, but with this kind of system working at the level of single photons, it would be much easier to do,” says Penty.

Another possibility is that of an entirely optical quantum-secured network. The Cambridge researchers have been developing optical switches that work with quantum signals, so that everything stays in the optical domain. “Effectively, this would mean that quantum IP routers should be possible, a concept that is now testable thanks to the quantum network,” says Wonfor.

So where else might quantum encryption be used? According to White, it could go into space. At the moment, quantum keys can be distributed up to a maximum distance of approximately 100 km of fibre, which is why the quantum network is built on a series of nodes, with a new quantum key being generated at each node. This setup works well in urban areas with a high number of users, but is not ideal for rural areas with few users. It also makes it impractical to send a quantum link across the Atlantic.

“An interesting movement within the field of quantum communications is to start involving satellites, so that you could produce a quantum communications link

for two remote sites,” says White. These satellites would work in parallel with fibre networks, sending quantum links to one of the trusted nodes within the network, where they could be managed, stored and distributed as needed.

The Cambridge group, along with several other academic and industrial collaborators, have recently secured several parallel funding bids from Innovate UK to develop both lower cost terrestrial and space-based quantum communications.

“The main thrust of all of this work has been to develop technologies that can be commercialised and put into regular use,” says White. “Cybersecurity is such an important issue, and we think that the laws of physics can be used to make our data transmission as secure as possible.”



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L E A P

The Metamorphosis

Credit: Entomics Biosystems and Stirling University



Maggots plus rotting food waste could be a new recipe for sustainable fish and animal feed – and a means to combat antimicrobial resistance, one of the gravest threats to global health and the future of modern medicine.

Imagine a warehouse with shelves of trays teeming with maggots munching their way through a meal of rotting fruit and vegetables. These larvae could become the sustainable food of the future – at least for fish and animals – helping reduce the reliance on resource-intensive proteins such as fishmeal and soy. They could also help to mitigate one of the causes of the increase in drug-resistant bacteria – the use of antibiotics in the food chain.

The company behind this idea is Entomics Biosystems. It was set up in 2015 by a group of students from the University of Cambridge, with venture support from the Cambridge Judge Entrepreneurship Centre's 'Accelerate Cambridge' programme.

"It's one of those stories where we came together in a pub over a pint, talking about weird ideas," explains its CEO and co-founder Matt McLaren. "The team has members from the Department of Biochemistry, from Engineering, from the [Judge] Business School, so it really is a diverse skill set."

According to the company, each year over 1.3 billion tonnes of food are wasted globally – equating to around US\$1

trillion of lost value. With an increasing population size and modern lifestyles, the burden of food waste on society and the environment is set to increase in the future.

Entomics focuses on 'insect biomass conversion'. Larvae of the black soldier fly chew their way through several tonnes of food waste collected from local supermarkets and food processing plants. The insects are fed different 'recipes' under controlled conditions to see how these affect growth rates and nutritional profiles. They metabolise the waste into fats and proteins, growing to around 5,000 times their body weight within just a couple of weeks.

As McLaren explains, these fats and proteins "are great sources of nutrition for salmon and poultry – in fact, insects are part of their natural diet". Entomics is currently working with partners including the University of Stirling, who are world-leading salmon aquaculture experts, to validate and test their products in the field.

"Farmed salmon in Scotland are currently fed on fishmeal which comes from wild-caught anchovies from as far away as Chile and Peru, which are then shipped across the world to Scotland," he explains. "Insects provide a sustainable solution."

With funding from Innovate UK and the European Institute of Innovation and Technology (through EIT Food, a £340 million project that involves Cambridge University), Entomics is using a novel bioprocessing technique to boost the nutritional and functional benefits of these insect-derived feeds, using a microbial



Words

Craig Brierley & Louise Walsh



Film available:

<https://bit.ly/2O6xmuF>



fermentation technology they have termed 'Metamorphosis'. Essentially, these specialised feeds represent a sustainable, holistic approach to improving overall fish health and welfare.

"There are several benefits to this process," explains Miha Pipan, Chief Scientific Officer and co-founder. "One benefit is in trying to preserve a healthier bacterial community in the animal gut. Another is to train immune systems to make livestock more resistant to disease challenges and at the same time reduce the need for veterinary medicines, antibiotics and vaccines."

With this latter aim in mind, the team at Entomics has been working with Dr Andrew Grant from Cambridge's Department of Veterinary Medicine and Dr Graham Christie from the Department of Chemical Engineering and Biotechnology to explore the use of the larvae as a pathogen defence mechanism in livestock.

Like all known species, insects make antimicrobial peptides (AMPs) within their bodies. These evolutionarily ancient molecules provide a level of innate immune defence against the pathogens they encounter in their environment – the same pathogens that are a problem in the food chain and in human and veterinary medicine. "Bacteria like *Campylobacter*, *E. coli* and *Salmonella* are a huge challenge to the livestock industry," explains Grant.

AMPs have retained antibacterial activity over millions of years, and combat pathogens using additional mechanisms to those used by antibiotics.

"What if we could protect animals through their feed using the AMPs found naturally in larvae?" asks Grant. "There is already evidence demonstrating the benefits of AMPs on growth performance in swine and poultry. We'd like to know whether these benefits include protection against infection and, if so, how the protection could be maximised to a level where antibiotics are no longer needed."

However, very little is known about the AMPs within these larvae. So, with funding from the Medical Research Council (through the Cambridge Academy of Therapeutic Sciences) and the Biotechnology and Biological Sciences Research Council, Grant and Entomics have embarked on one of the first studies to find, purify and characterise these tiny peptides.

"We want to ask questions like are the peptides specific for certain pathogens or do they have a broad range of protection?" says Grant. "Do they increase in concentration in the larvae if they are grown in the presence of pathogen? Can the larvae be genetically engineered to provide therapeutic compounds for the medical and veterinary sectors?"

Entomics believes the potential for wider innovation in the emerging insect industry is hugely promising, and is also working on an engineering project to build a smart, modular system for insect production in the future. This includes developing computer vision algorithms to understand and monitor insect behaviour

during the production process – for example, the insects' growth and health.

"The world's looking for more sustainable sources of feed, and I think increasingly there's a recognition that it's not just about basic nutrition, but also about overall health," says McLaren. "We're trying to take a promising, sustainable ingredient of the future – these insect-derived feeds – and trying to add a bit of biotechnology or science focus to it, to really enhance what the effect is in the end application and reduce reliance on traditional antibiotics and veterinary medicines."

Black soldier flies spend their short week-long lives searching for a mate, reproducing and laying hundreds of eggs in the decomposing detritus on which their larvae will gorge. The hope now is that their industrious activity will kick-start a new generation of innovation that has applications in food security, food waste reduction, renewable resources, novel bioreagents and therapeutics. A metamorphosis is in the making.

www.entomics.com



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“Forgive the haste, the messenger is waiting”



“Philologists are workers in the engine room of history. We’re the ones covered in oil”

From difficult-to-read “enigmatic squiggles”, scrawled in a hurry to catch the next ship, come fascinating insights into a Mediterranean melting pot of communities three centuries ago. It’s all in a day’s work for the skilled philologists who decipher, translate and interpret.

It’s difficult, admits Professor Geoffrey Khan, to make philology into a buzz word.

Philology is the study of languages in written sources, and it’s a discipline that Khan is keen to champion. As he points out, without the painstaking work of scholars who are able to read and translate historical texts, many primary sources would not be available to historians. Says Khan: “Philologists are workers in the engine room of history. We’re the ones covered in oil.”

Cambridge University has long been a centre for the study of manuscripts, a field that depends on a brand of scholarship honed over many years of dedicated study. The philologist must be both

expert linguist and patient cryptographer. Yet, philologists are specialists whose contributions to scholarship are rarely acknowledged outside academia.

“It takes many years of training in languages and many hours of slow, painstaking deciphering of barely legible and fragmentary manuscripts to be able to save important historical texts from oblivion and present them to the world in editions,” says Khan, who is the Regius Professor of Hebrew in the Faculty of Asian and Middle Eastern Studies. The manuscripts that throw light on history are written not solely by scribes but also by individuals whose messages were penned in a rush to catch the next ship.

“Even when the texts are finally deciphered, they are often obscure and require skills of interpretation based on familiarity with many other texts. Only then can a translation be made. These text editions and translations, which are the product of hundreds of hours of work in the hidden philological engine room, are the foundation of meaningful



Image

Manuscript fragments from the Genizah before conservation and analysis

advances in historical research.”

Cambridge University Library is custodian of thousands of precious manuscripts, vital keys to understanding the past. In the 1890s, the Library became guardian of two-thirds of the world’s arguably greatest collections of Jewish manuscripts. Thousands of texts from the Cairo Genizah, a repository from the oldest synagogue in the Egyptian capital, were famously secured in the 19th century by the scholar Solomon Schechter, whose trip was funded by the Master of St John’s College, Cambridge.

By virtue of further acquisitions, Cambridge’s Cairo Genizah collection now comprises around 200,000 paper and vellum fragments written chiefly in Hebrew and Arabic. For more than 100 years, scholars have been unlocking the stories the collection tells about life in multicultural Cairo and beyond. Although much

of this research has focused on the archive’s medieval documents, which date from the 10th to the 13th centuries, the archive also contains hundreds of letters written by Jewish merchants living in Cairo many centuries later when the city still had a thriving Jewish population.

In a joint project with colleagues Dr Esther-Miriam Wagner and Dr Mohamed Ahmed (both at the Woolf Institute in Cambridge), Khan is looking at these 18th and early 19th-century letters, which are written in Arabic language using Hebrew script – a form known as Judaeo-Arabic. For centuries, Jewish law forbade the destruction of any text mentioning God, and synagogues were used as repositories. Documents from the Genizah offer a precious snapshot of Jewish networks across the western Mediterranean.

“What makes merchants’ letters so interesting for linguists is that traders, unlike the scribes who pen more official correspondence, use an informal style and employ many colloquialisms,” says Wagner. “The immediacy of their circumstances shines through in speedily written apologies such as *Forgive the haste, the messenger is waiting*. They

write in a condensed style and are trendsetters for new language forms.”

The mercantile world of the 18th and early 19th-century Mediterranean was a melting pot of communities spanning many faiths. The merchants’ letters that survive in the Cairo Genizah, while offering a vivid glimpse of Jewish life, represent just one dimension of a much bigger trading picture.

“Jewish merchants were Arabic speaking but they wrote in Hebrew script. This was an outcome of their schooling which placed emphasis on being able to read the Bible in Hebrew,” says Wagner. “To get a bigger picture we needed to find documents written in Arabic as well.”

In 2012, a chance meeting intervened to add another piece to the jigsaw. At a conference in London, Wagner learnt that the Prize Papers Collection in the National Archives in Kew Gardens contain a box of business letters in Arabic and Hebrew script. The letters had been seized in 1759 by British seafarers as part of the cargo on a Tuscan ship bound from Livorno in Italy to Alexandria in Egypt.

“All the pleas, compliments, threats and accusations never reached their intended recipients”

“When I was asked if I’d like to work on this correspondence, it was stupendously exciting,” says Wagner. The 75 documents had lain largely undisturbed for over 250 years. Most of them were unopened.

“All the pleas, compliments, threats and accusations never reached their intended recipients. Because the envelopes were still sealed, we were able to learn how they would have been distributed. One large envelope, addressed to a prosperous merchant, contained ten smaller ones to other suppliers. Folded inside the letters were lists of commodities,” says Wagner.

“The contents give us a vivid picture of trade with wool, pewter, cochineal and wood travelling to Egypt from Italy, and coffee, silk and spices coming from Egypt to Europe. This information is hugely useful to economic historians. We also read of life abroad for migrants (*Italy is such a free country*), family concerns (*I am exhausted with the kid*), and health (*we sent you the [kidney] stone in a purse... so you can see it*).”

The Prize Papers correspondence also provides an opportunity to investigate the

interaction between Christian, Jewish and Muslim merchants across borders in the 18th-century Mediterranean.

Wagner explains: “These letters will throw new light on the history of interfaith relations. Commerce is an arena in which people deal with each other on a business basis regardless of their differing religious backgrounds. The sense of cohesion that comes from being part of a trade network may be as important a component of identity as being a Jew, Muslim or Christian. For instance, when a Christian merchant writes to his Muslim partner in Alexandria, he makes sure to use a formula that unites their respective religious communities, invoking a common faith background that includes all ‘prophets’ and ‘messengers’, Jewish, Christian and Muslim.”

Ahmed, a scholar from Egypt, is playing an important role in the project to read and translate the Prize Papers. Wagner says: “As a native speaker, not only is Mohamed familiar with the more obscure colloquial expressions in Arabic that are so often used by merchants, but he’s also brilliant at reading the trickiest handwriting in Arabic script, and is able to decipher the most enigmatic of squiggles that sometimes confound the rest of us.”

The meticulous groundwork carried out by philologists working on apparently obscure documents is often overlooked, Wagner says. “Philologists work closely with other specialists, such as palaeographers who study handwriting and codicologists who work on the physical nature of manuscripts. Together, we provide the source material that historians, economists and linguists need to advance our understanding of the past. The letters we’re studying, for example, show just how highly cosmopolitan and interconnected trading ports were three centuries ago.”

Khan’s dedication to passing on the skills of philology has resulted in a worldwide community of scholars, of whom Wagner is just one. He says: “We have fabulous graduate students, from all over the world, who continue the tradition of careful deciphering, translating, interpreting and editing manuscripts.”



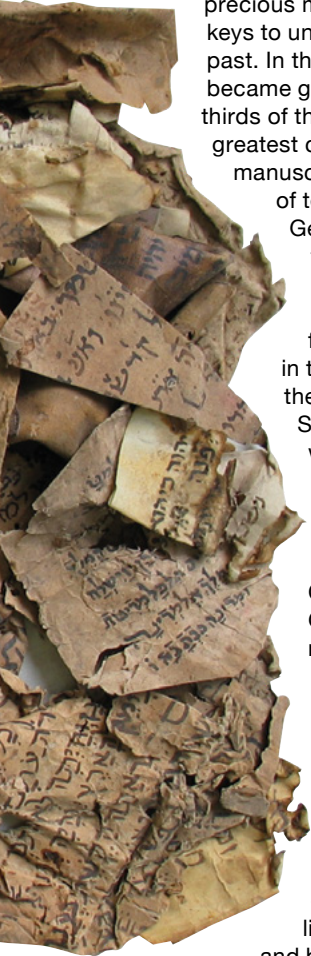
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Words
Alex Buxton



Preparing to meet other Earths

New exoplanet-hunting telescopes will start searching the skies for other worlds in the next few years. In the build-up to these observations, Dr Oliver Shorttle – one of a new group of interdisciplinary physical scientists in Cambridge – is developing geological methods to reveal whether any of these worlds resemble our own.

Earth is amazing. Over its 4.5 billion years of life, the planet has been redistributing heat and myriad chemical species between its deepest interior and its outer surface. It's a cycle of rejuvenation and replenishment that produces our climate, atmosphere and nutrients to sustain life. Volcanic eruptions supply gases to our atmosphere, put fresh rock on the surface and add nutrients to the oceans; carbon is drawn out of the atmosphere, locked away in the sedimentary crust and pulled into the Earth's deep interior by tectonic plates.

Amazing... but is it unique? "When we consider the question 'is Earth unique in the universe?' we come up against the $n=1$ problem: our understanding of Earth is limited by it being the only Earth-like planet we have to study," says Dr Oliver Shorttle. As an Earth scientist,

he is fascinated by the history – and the future – of our planet and its oceans, atmosphere and biosphere. Like others in the discipline, he is trying to reconstruct how the planetary system developed and works, using the tangible record we have of the Earth's past: its rocks.

"In some respects, being an Earth scientist is like being a zoologist with only one animal to study," says Shorttle. "What if we could change the $n=1$ problem to $n=10$ or $n=100$? Suddenly we come closer to answering major questions about how Earth-like planets evolve," he says. "Understanding Earth's own history requires us to leave Earth and look elsewhere."

Shorttle is a new type of Earth scientist – one whose focus is not just on the planet on which we stand but also on planets that orbit suns other than our own, so-called exoplanets.

A new generation of telescopes will make these detailed observations of exoplanets possible: NASA's Transiting Exoplanet Survey Satellite (TESS), which launched in April 2018, and the James Webb Space Telescope (a collaboration between NASA, the European Space Agency and the Canadian Space



Image

Computer-generated images of exoplanet types

Primed for life

Cambridge scientists are not only looking for exoplanets with atmospheres like ours, they're also looking for those with the same chemical conditions that may have led to life on Earth.

A team of physicists and molecular biologists have recently discovered that stars which give off sufficient ultraviolet (UV) light could kick-start life on their orbiting planets in the same way it likely developed on Earth.

Three years previously, molecular biologist and co-author on the new study Dr John Sutherland successfully generated precursors to lipids, amino acids and nucleotides using hydrogen cyanide (HCN) and UV lamps in the laboratory. His hypothesis is that the heat from meteorite impacts converted ambient nitrogen and carbon into cyanide, which rained to the surface. There, powered by light from the Sun, it interacted with other elements to generate the building blocks of life.

"I came across these earlier experiments," says physicist and lead author of the new study Dr Paul Rimmer. "As an astronomer, my first question is always what kind of light are you using? I started out measuring the number of photons emitted by their lamps, and then realised that comparing this light to the light of different stars was a straightforward next step."

The two groups measured how quickly the building blocks of life can be formed from HCN and hydrogen sulphite ions in water in the presence and absence of UV light. They then compared the light chemistry with the dark chemistry against the UV light of different stars.

"Getting some idea of what fraction of terrestrial planets in the observable universe might be primed for life fascinates me," says Sutherland, from the MRC Laboratory of Medical Research. "Of course, being primed for life is not everything and we still don't know how likely the origin of life is, even given favourable circumstances."

However, the work allows the researchers to narrow down the best places to search for life, says Rimmer. "Life may have developed in different ways but, to start with, it makes sense to look for places that are most like us. It brings us just a little bit closer to addressing the question of whether we are alone in the universe."

Agency), which is due to launch in 2021.

The first exoplanet, 51 Pegasi b, was discovered as recently as 1995 by Professor Didier Queloz from Cambridge's Department of Physics when he was a PhD student in Geneva. Until then, although astronomers had speculated as to the existence of these distant worlds, no planets other than those in our own solar system had been found. Now, over 3,500 exoplanets are known.

"Now we are on the cusp of a second revolution in exoplanetary science," says Shortt. "Thanks to the new telescopes, we'll be able to characterise these planets beyond their mass and orbit – we'll be able to study their atmospheres."

But, says Shortt, just knowing what the atmospheric conditions are like on an exoplanet isn't enough. "Many of the exoplanets we already know of are remarkably unlike anything we've seen in our own solar system. We will need to be able to interpret what any particular atmosphere means by understanding the fundamental geological processes that could have formed it. So in the build-up to receiving the space observations, we need to model what these 'geological signatures' mean."

His research focuses on volcanism – a universal planetary phenomenon that on long timescales forms atmospheres and on short timescales perturbs them. He and colleagues are building models to explain how different atmospheres are formed. "The idea is to use observations from the new space telescopes to

'work backwards', opening up a window into the interiors, tectonics and geological history of terrestrial exoplanets," he explains.

Shortt is also working with physicists like Dr Paul Rimmer and Queloz to understand the geological environment needed for life to begin (see panel). "Any small twist of fate could have stopped life from forming on Earth... not enough wet and dry, the wrong kind of light... the simplest things place constraints."

Integrating Earth sciences with astrophysics is one part of a major new initiative in physical sciences to promote interdisciplinary activity; six new tenure-track researchers have been recruited across various disciplines to enable a wave of new discovery.

"we are on the cusp of a second revolution in exoplanetary science"

"On paper my remit is absurdly interdisciplinary," enthuses Shortt. "Trying to understand how Earth operates already requires a collection of disciplines. The study of exoplanets is taking this further. An even broader menagerie of understanding of physical, chemical and biological processes will be needed simply because we don't know what's out there."

He adds: "I see my role as making connections that will turn astronomical observations into a picture of the geology of these new worlds, and in turn help our understanding of Earth's own evolution."

"Exoplanets might shed light on the events that brought Earth to its present. What, for instance, if we find a planet that looks just like Earth but that never evolved life – that would tell us something truly profound about our own existence."

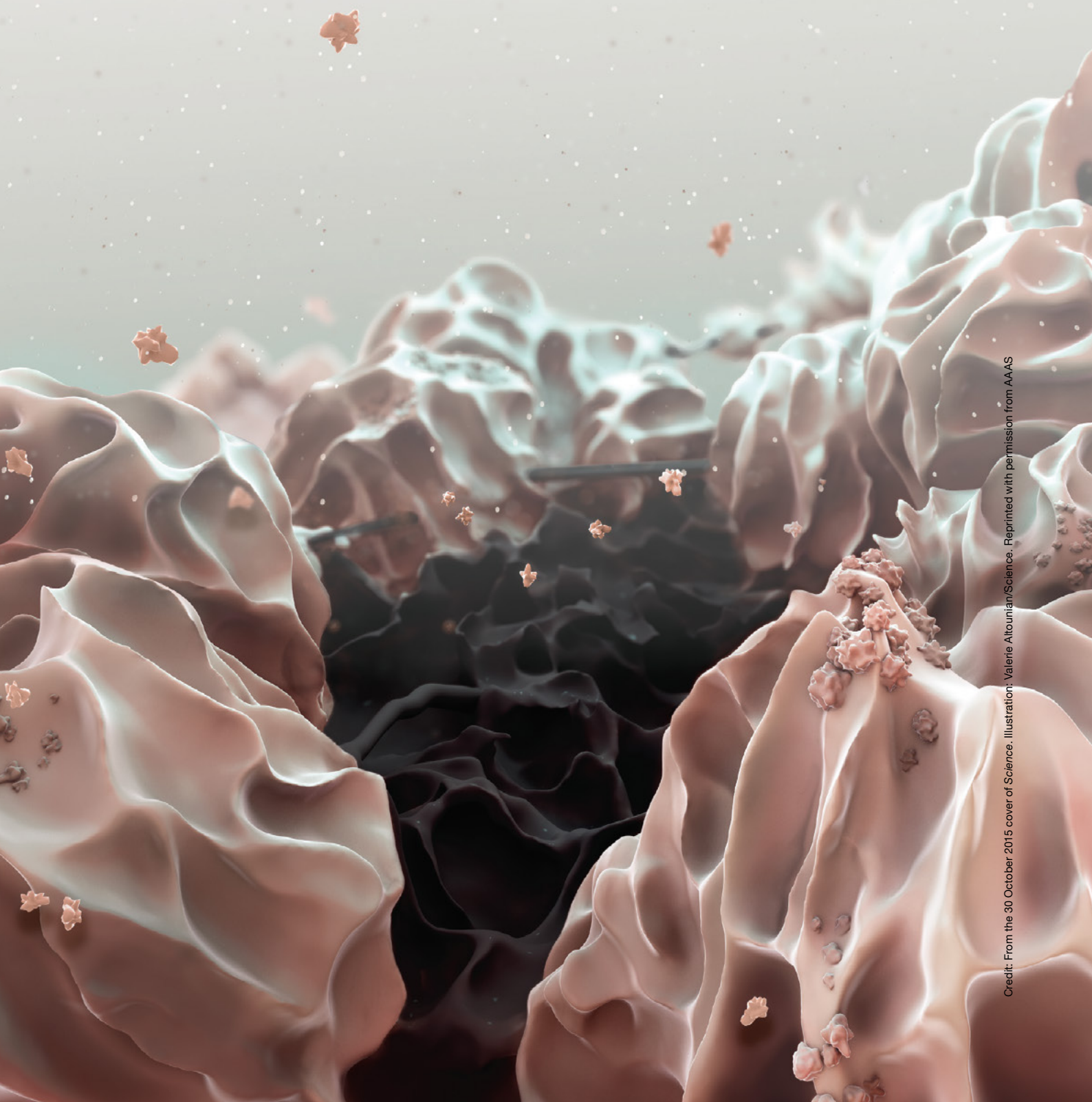


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Words
Louise Walsh

What does it take to make a better battery?



Credit: From the 30 October 2015 cover of Science. Illustration: Valerie Atounian/Science. Reprinted with permission from AAAS

Cambridge researchers are working to solve one of technology's biggest puzzles: how to build next-generation batteries that could power a green revolution.

Like many of us, when I wake up I reach for the phone on my bedside table and begin scrolling through Twitter, Instagram, email and news apps. I listen to streamed music as I get ready for work and podcasts during my commute. By the time I reach the office, my phone already needs a boost. It's not even 9am.

It's a modern miracle that we have computers in our pockets more powerful than those which supported the moon landings. But, despite the fact that the transistors inside our phones and laptops have been getting smaller and faster every year, the batteries that power them have not.

The key to making electronics portable – and powering a sea change in how we communicate and consume information – was the commercialisation of lithium-ion batteries by Sony in 1991. Lithium-ion batteries are rechargeable, so when the device is connected to a charger it restores the battery for another use.

While lithium-ion batteries have undeniable advantages, such as relatively high energy densities and long lifetimes in comparison with other batteries and means of energy storage, they can also overheat or even explode and are relatively expensive to produce. Additionally, their energy density is nowhere near that of petrol. This makes them unsuitable for widespread use in two major clean technologies: electric cars and grid-scale storage for solar power. A better battery could make all the difference. So what's holding up progress?

Professor Clare Grey is one of the UK's leading battery researchers, and heads a large research group in Cambridge's Department of Chemistry. Using methods such as NMR spectroscopy, her group studies materials that could be used in next-generation batteries, fuel cells and supercapacitors.

A better battery is one that can store a lot more energy or one that can charge much faster – ideally both. Grey's group is developing a range of different next-generation batteries, including lithium-air batteries (which use oxidation of lithium and reduction of oxygen to induce a current), sodium batteries, magnesium batteries and redox flow batteries.

A working lithium-air battery, for example, would have a theoretical energy density ten times that of a lithium-ion battery, giving it potential applications in portable electronics, transportation and grid storage. However, although this

high energy density would be comparable to that of petrol, the practical energy density achievable is noticeably lower and significant research challenges remain to be addressed.

While Grey works with industrial partners to improve the batteries going into electric cars today, she says the role of universities is to think about entirely new types of batteries, such as the ones she is developing in her lab.

"Universities need to be coming up with answers for ten to 15 years from now – we're the ones who are best placed to innovate, think creatively and generate radical, new solutions," she says. "We want to make sure that our work has an impact well beyond today's batteries."

In addition to developing entirely new types of batteries, a major strand of Grey's research is the detection of faults. As part of her Professorship funded by the Royal Society, Grey is trying to find ways to locate faults in batteries before they happen.

"If we're serious about switching to a low-carbon economy, we need to be thinking about how to solve these problems now"

"Can we detect indicators of faults in batteries before they go wrong? If we can find them, then we could potentially prevent batteries from exploding. In addition, we want to explore whether a car battery that's reached the end of its life could have a second life on the grid, for example. If we could work out, in real time, what causes the battery to degrade, we could change the way we use the battery, ensuring it lasts longer," she says. "The more we know about the state of health of a battery, the more valuable that battery becomes. Both strategies – increasing battery life and finding a second use – lead to cheaper batteries."

Grey is also heavily involved with the Faraday Institution, the UK's independent national battery research institute, funded by the government through its Industrial Strategy. She is leading one of four 'fast start' projects, with nine other university

and ten industry partners, to examine how environmental and internal battery stresses (such as high temperatures, charging and discharging rates) damage electric car batteries over time.

"When you think about other electronic devices, you're generally only thinking about one material, which is silicon," says Dr Siân Dutton at Cambridge's Cavendish Laboratory in the Department of Physics, and who is also working on the Faraday Institution project. "But batteries are much more complex because you've got multiple materials to work with, plus all the packaging, and you've got to think about how all these components interact with each other and with whatever device you're putting the battery into."

Among other projects, Dutton's research group is investigating the possibility of a battery electrolyte that is solid instead of liquid. One of the primary safety concerns with lithium-ion batteries is the formation of dendrites – spindly metal fibres that make a battery short-circuit, potentially causing the battery to catch fire or even explode.

"If the electrolyte is solid, however, you may still get dendrites, but the batteries are far less likely to explode," she says. "It's important for universities to look at unconventional battery materials like the ones we're investigating. If everyone moves in the same direction, we won't get the real change we need."

The prospect of an electric car with a range of 1,000 miles, or an iPhone that charges in two minutes, or being able to use stored solar power after the sun goes down, may all be some years away. But, says Grey: "If we're serious about switching to a low-carbon economy, we need to be thinking about how to solve these problems now. We're continuing to push new materials and new methods because, without them, research fields stagnate."



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Words
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Image
False-colour microscopic view of a reduced graphene oxide electrode (black, centre), which hosts the large lithium hydroxide particles (pink) that form when a lithium-air battery discharges

Things

A story unfolds

An alternative history of reading is being explored through new research on a collection of 'moveable' books – and with the help of two children called Fanny and Henry.

Tabs, flaps, strings, wheels, cut-outs, even tiny sound machines – all manner of movement can be found in Cambridge University Library's extraordinary collection of children's books.

Take the stories of Fanny and Henry who, through several unfortunate turns of events, become separated from their parents and embark on a series of adventures that refine their characters, before finally returning home. As the plots twist and turn, so the reader can change the outfits of paper dolls, and invent their own tales of fortune and misfortune for the intrepid children.


Produced by Samuel and Joseph Fuller, and sold at their aptly named Temple of Fancy and Juvenile Museum in Rathbone Place, London, from 1810 to 1817, the paper dolls tell their own story today. Some are grubby and worn, with hats likely to be missing, as the flimsy hand-painted cut-outs bear the imprint of excited readers more intent on imaginative play than on moralistic stories.

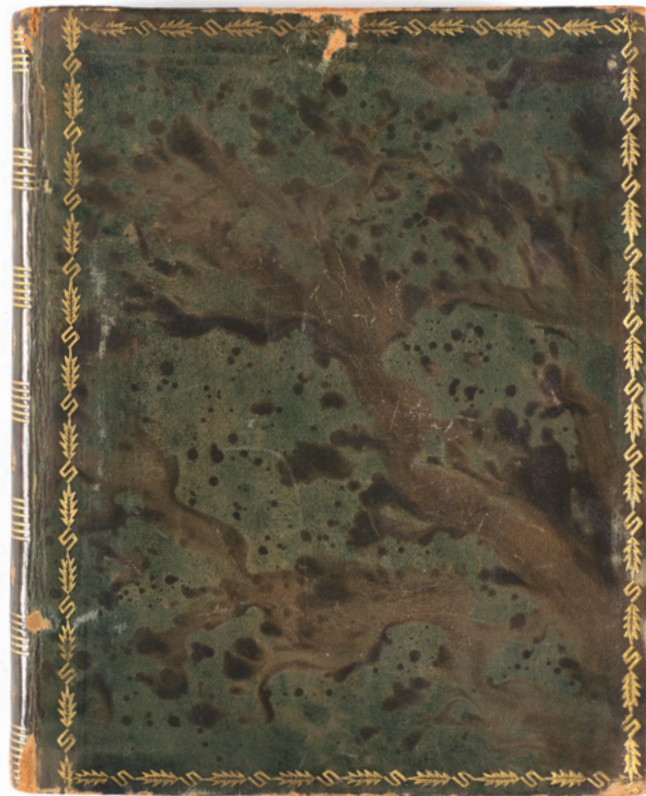
It is these subtle signs of use that intrigue Dr Gill Partington, the Library's new Munby Fellow. Using the Library's special collections, including the recently catalogued items held in the Library's Tower, Partington will explore how these overlooked "unorthodox variants" of books can inform our understanding of how we use a page, what constitutes a book and when reading really begins.

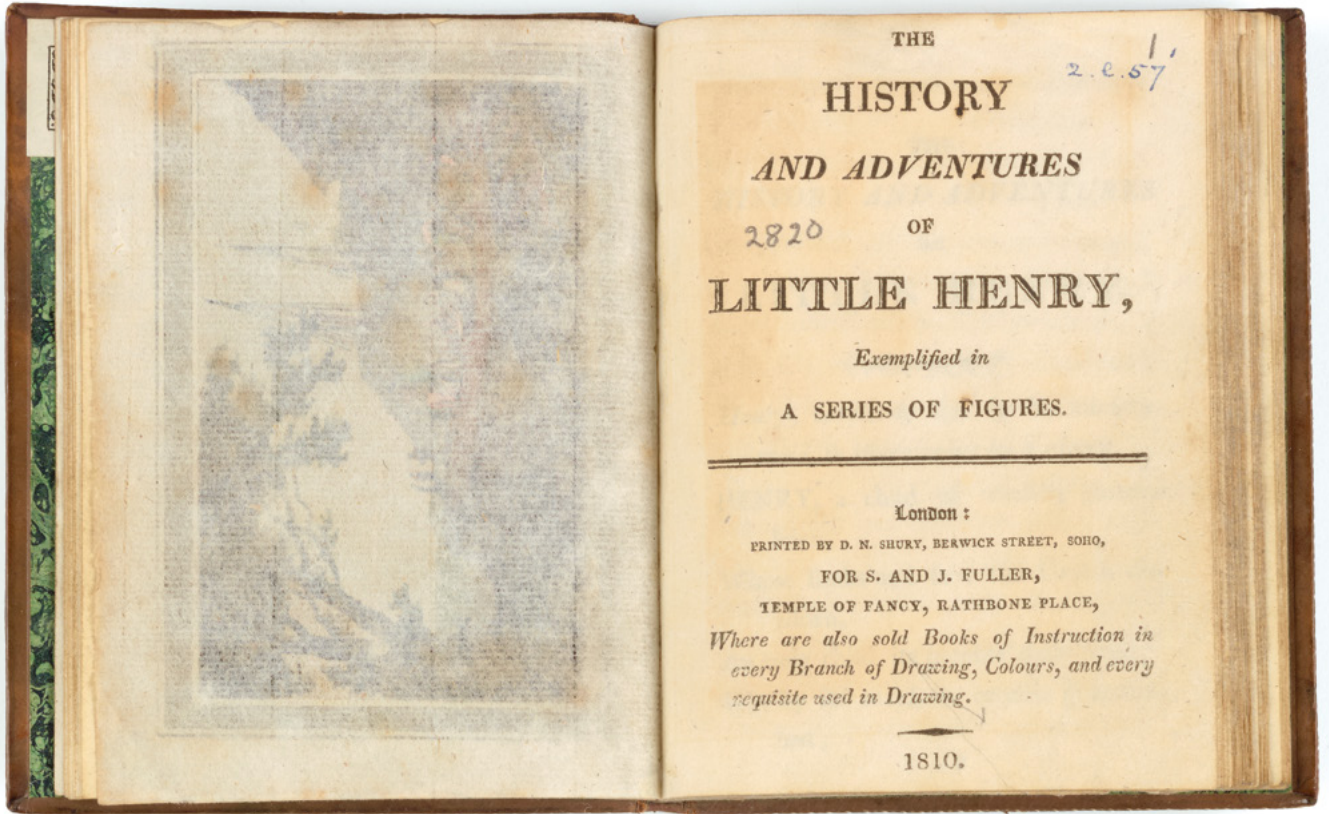
"My research is not just on the objects themselves but on the interaction between books and bodies," she explains. "Children break the rules in ways that make you think about what the rules of reading are in the first place."

Her work will culminate in the compilation of a new website that will be a vital resource for others seeking to uncover the alternative history of reading.

www.lib.cam.ac.uk

 **Words**
Charis Goodyear





The glue that builds a strong child



Words
Craig Brierley

Our brains continue to take shape for several years after we are born, making this a particularly vulnerable time for our development. Here, in the first of three articles that focus on the developing brain, we ask: could the early moments of a newborn baby be a crucial window for helping prevent problems in later life?

Most animals are born relatively complete: a newborn gazelle, for example, is running within a couple of hours of birth. Not so for humans: for us, birth is very much just the beginning.

“In a newborn baby’s brain, many cells haven’t gotten where they need to go,” explains Professor David Rowitch, Head of Cambridge’s Department of Paediatrics. “We think this ‘commuting’ process is vulnerable to adverse events. A lack of oxygen or infection, for example, might block cell movement and derail the schedule of brain circuit formation.”

He and colleagues have shown that neurons travel extensively in the brain as part of this schedule – which makes this a vulnerable time for developing infants. Take a preterm infant born after six, rather than nine, months in the womb. It will spend its early life in a neonatal intensive care unit and has a higher risk of having medical and neurological complications. Such an infant, says Rowitch, is also at risk of mental health problems in later life.

“Because these are not kids who are genetically predisposed to mental health conditions, something must have happened to them early in their life that made them at high risk – that’s an important clue.”

What that ‘something’ is may relate to Rowitch’s own research on the preterm brain – and particularly its ‘building blocks’, cells known as neurons and glia.

‘Glia’ literally means ‘glue’, a rather nondescript term – an indication, he says, of how their importance has been overlooked by neuroscientists. Yet it’s becoming increasingly clear that glia are essential to brain development, in assembling neural circuits and in helping brain centres communicate with each other and the body.

Crucially, glia provide myelin to insulate the nerve tracts during development.

“In a newborn baby’s brain, many cells haven’t gotten where they need to go”

Rowitch believes that abnormal glial function plays an important role in the development of neurological, cognitive and mental health problems later in life.

He explains that if these circuits need to balance each other, and there is an adverse event like preterm birth, then suddenly there will be an imbalance in the brain. “Migration of neurons is a relatively late process in the human brain, so problems that affect the newborn may be sufficient to explain long-term problems such as cerebral palsy and cognitive and mental health problems. It could also provide clues to disorders like autism.”

But bridging the diagnosis and treatment of physical changes in the developing brain to the diagnosis and treatment of mental health disorders faces a challenge, he says. “While the majority of mental health problems manifest in children, teens and young adults, the norm for healthcare is that physical and mental health are treated separately, usually at entirely different clinics.”

This seems particularly disjointed when one considers children with eating disorders or those with chronic diseases, who are particularly vulnerable to depression. While there is increasing evidence that genetic factors can increase a child’s vulnerability to mental health conditions, this is clearly not the whole story.

In the clinic, Rowitch and NHS colleagues believe the time is now to bridge the divide between physical and mental health. A vision being developed for a new Children’s Hospital on the Cambridge Biomedical Campus integrates both facets and develops a holistic approach to healthcare.

This would mean that a child with an eating disorder, for example, would be seen

by both psychiatric and medical specialists, and a child with a chronic disease would see a psychiatrist, providing early detection and intervention for mental health.

“We need to move away from silos,” Rowitch says. “And this is where Cambridge, with strengths across the board from genomics to complex medical care, child and adolescent psychiatry, is perfectly positioned to lead by example.”

“It has been said that it is easier to build strong children than to repair broken men,” he adds, quoting the words of 19th-century American abolitionist and ex-slave Frederick Douglass. “If our vision can be realised, then Cambridge could help ensure there are fewer ‘broken’ men and women to repair in future.”

David Rowitch is funded by the Wellcome Trust, European Research Council, National Institute for Health Research and National Institutes of Health (USA).



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Struggling with labels

Labels help us make sense of the world – but only to a limit, as scientists are finding. In the second of our articles on the developing brain, we look at how the latest techniques are helping to develop a more nuanced understanding of learning disorders – and to identify new ways of supporting those who struggle at school.

The education system is awash with labels: pupils are dyslexic, have attention deficit hyperactivity disorder (ADHD), are visual learners, kinaesthetic learners.

Sometimes, these labels have found common currency and yet are based on no credible evidence. Take ‘learning styles’: visual, auditory or kinaesthetic. These seem to make sense – I always assumed I was a kinaesthetic learner as I learn by doing things.

The problem is that these styles are “nonsense”, says Dr Duncan Astle from the Medical Research Council (MRC) Cognition and Brain Sciences Unit in Cambridge. “Children will tell you they have a preferred learning style, but they’re no better in their preferred style. In fact, there are probably some dangers to telling a child that they’re a kinaesthetic learner

or whatever, because then when you try teaching them in a different format, they think ‘What’s the point in paying attention? This isn’t in my preferred style.’”

Other labels, particularly those based on clinical diagnoses – dyslexia, dyspraxia, ADHD, for example – can be helpful in ensuring a child receives specialist support. But diagnosis is a “thorny issue”, Astle says. These conditions are complex, their causes poorly understood, and children will often meet the diagnostic criteria for multiple disorders. This makes studying them, and hence developing effective interventions, challenging: one child’s ADHD may be very different from another’s. As Astle says: “The labels don’t fully characterise what the child struggles with.”

Together with colleagues Susan Gathercole and Joni Holmes at the Centre for Attention Learning and Memory, Astle sees hundreds of children who have been referred by health and education professionals for problems in attention, memory, language or poor school progress.

Rather than grouping them together according to a clinical diagnosis, the team applied machine learning to identify children with common cognitive problems. They found that the children

could be split into four broad cognitive profiles: children with verbal cognition problems (or ‘phonological difficulties’), those with working memory problems, those with more severe problems across the board, and those who do not appear to have any cognitive problems but still struggle at school.

These cognitive profiles may allow for more effective ways of supporting the children, says Astle. He gives the example of a typical problem that might confront a child with working memory problems.

“If you spend time in a primary school, you soon learn that if you can’t follow a list of instructions, you’re stuffed. ‘Hang your coat up, go to the table, pick up a card and a green pen, and come and sit in front of me.’ Even copying things down from the board will be very slow and error prone if you can only hold one or two letters in mind at a time.”

Problems with working memory can soon spill over to other aspects of learning, so if a teacher can limit the number of instructions or the amount of copying from the board, for example, then this could benefit the child’s overall learning and development.

Astle’s team has been looking at whether ‘brain training’ could help



Words
Craig Brierley

When a speech signal comes into the brain, it acts as a 'reset button' to these cell assemblies, which then align their vibrations to the rhythm of the speech: when they are accurately aligned, speech becomes intelligible.

When Goswami analysed the speech patterns of parents talking to infants – for example using nursery rhymes and exaggerated baby speech – she found that they emphasise the delta frequencies. "My work suggests that this delta frequency, which helps you perceive the stress patterns used in all languages to convey meaning, is the foundation of language. Once you've got that skeleton, you can start adding things, like the syllables, the single speech sounds, the phonemes."

Crucially, she showed that, for children with dyslexia, their delta networks were out of phase with the speech patterns. It appeared that they were missing the initial 'reset' command.

It isn't clear yet why this should translate into problems with spelling and

reading, but, says Goswami, "there's something about reflecting on sound as an abstract pattern that you need for learning a system of spelling. Even if you're learning a straightforward language like Italian or Spanish, if you have these phonological and acoustic processing problems, it's still a very hard task for your brain."

If you can intervene before a child is faced with learning to read, you may have a better chance of limiting the impact of the disorder. Goswami has developed a music and poetry activity to encourage pre-schoolers to learn speech rhythm patterns and develop phonological awareness – "things that used to be ubiquitous in the playground, like clapping games, matching beats to syllable beats in language, marching games, drumming, even poetry out loud."

She is also working with a team at the University of Jyväskylä in Finland on a children's 'brain training' app that will help reinforce these skills – the English language version has recently been licensed by Cambridge Enterprise, the commercialisation arm of the University. The app, GraphoGame, has been shown to be as effective as one-to-one teacher support but any number of children can be playing at the same time.

Goswami is particularly enthused by the idea that, in future, infants at risk of dyslexia – for example if they have a parent with the condition – may be able to use a device that hooks over the ear and helps to amplify the elements of speech that are not processed correctly. She has received funding from the MRC and the Fondation Botnar to develop a proof of principle.

"It could eliminate dyslexia," she says, excitedly. One way of getting to the root cause of learning disorders could be to identify infants at greatest risk and to see how their brains develop in the first few months – or even days – after birth. This

these children. The researchers showed that just 40 minutes of training per day focused on working memory led to improvements – and to changes in brain connectivity – although the benefits were limited. "They get better at the thing they're training on and closely adjacent skills, but the kids who undergo this kind of training don't spontaneously get better at maths or start experiencing fewer symptoms of ADHD," he says.

Brain training is becoming an increasingly popular way to help children overcome their learning difficulties. Professor Usha Goswami from the Centre for Neuroscience in Education is working on a game that could help children with dyslexia, for example.

Surprisingly – and possibly as a result of the heterogeneity of learning disorders – opinion is still divided over what the condition actually is. Dyslexia literally means 'difficult reading', implying that it is a visual condition. Not so, says Goswami, who argues that dyslexia is about how we process speech.

Speech is transmitted as a sound wave. It's interpreted by brain cells that vibrate at several different frequencies, for example delta (1–3 Hz) and theta (4–8 Hz). The delta frequency relates to the perception of stress patterns in speech, theta to syllable segmentation.

“It could eliminate dyslexia”

is not without its challenges, as Professor Mark Johnson, Head of Psychology, knows too well.

Johnson joined Cambridge recently from Birkbeck, University of London, where he pioneered research into infants’ and toddlers’ brains at the world-renowned Babylab. He is now turning his attention to an even earlier stage, the period from immediately before birth to the first few months after.

“Most people will agree that the biggest change in environment that the brain has in its lifetime is birth,” he says, “going from being a baby in the womb to being outside within a couple of hours, in a world with human beings, lights and everything. It’s clearly a very dramatic event for the brain.”

In collaboration with Professor Topun Austin at the Rosie Hospital in Cambridge, and building on earlier work by Professor Simon Baron-Cohen at the Autism Research Centre, Johnson plans to use the latest prenatal MRI and ultrasound techniques to study the behaviour of the baby in the womb. It’s been clear for a while that the fetus has a “behavioural repertoire”, he says. A recent study, for example, showed that a fetus will follow a light source shone onto the mother’s abdomen.

Once the babies have been born, he hopes to observe their brain development over their first few days in the outside world. Babies’ skulls are relatively thin and translucent. By shining infrared light on a newborn’s head, it’s possible to observe subtle changes in the colour of the blood, which becomes bluer as

activity (and hence oxygen) levels in a brain region fall, and redder when they increase. Using this technique, known as near-infrared spectroscopy, Johnson wants to validate initial data that suggests there are dramatic changes in brain function over the first few days.

His research has already shown how certain brain regions ‘tune up’ during infancy, such as the area that in adults has been shown to process faces.

“In infants, those same regions respond to faces, but they also respond to other complex objects,” he says. “Over time, they become selectively interested in faces. This could be one of the processes that goes awry in autism, where the part of the brain that responds to social stimuli has not been properly tuned.”

This is unlikely to be the whole story, however. Johnson points out that there are also other, more generalised problems in autism, such as subtle motor delays and problems with visual and auditory perception, which then manifest in social challenges later in life.

Johnson believes that these later manifestations may arise from the autistic child’s inability to process complex information. “If you’re a 12-month-old, the most complex aspect of the external world is other human beings. They’re unpredictable, they’re dynamic, they make sounds, they smell. It’s a massive challenge to understand the social world, which might explain why autistic children prefer stimuli that are repetitive or more predictable.”

He agrees with Astle that understanding and measuring brain function is better than applying labels. When trialling interventions to help ameliorate some of the traits of these conditions, brain measures are better than clinical tools at predicting outcome.

This move away from broad labels and towards a more nuanced approach is reflected in the latest edition of the

American Psychiatric Association’s *Diagnostic and Statistical Manual of Mental Disorders (DSM-5)*, which has moved towards ‘dimensions’ of symptoms of autism rather than categories (the term ‘Asperger’s’ is now classified within the Autism Spectrum, for example).

“In the past, we’ve been overly reliant on biomedical models,” Johnson says. “People tend to think of autism and ADHD as diseases, when they in fact describe a series of behaviours. It’s not right to think of them in the same way as, say, the flu.”

As humans, we like labels: they help us categorise and simplify the world around us. We may not be able to dispense with labels like autism and dyslexia anytime soon, but if science is teaching us anything, it’s to look beyond the label and remember that behind it lies a unique – and complex – individual.



Dr Duncan Astle

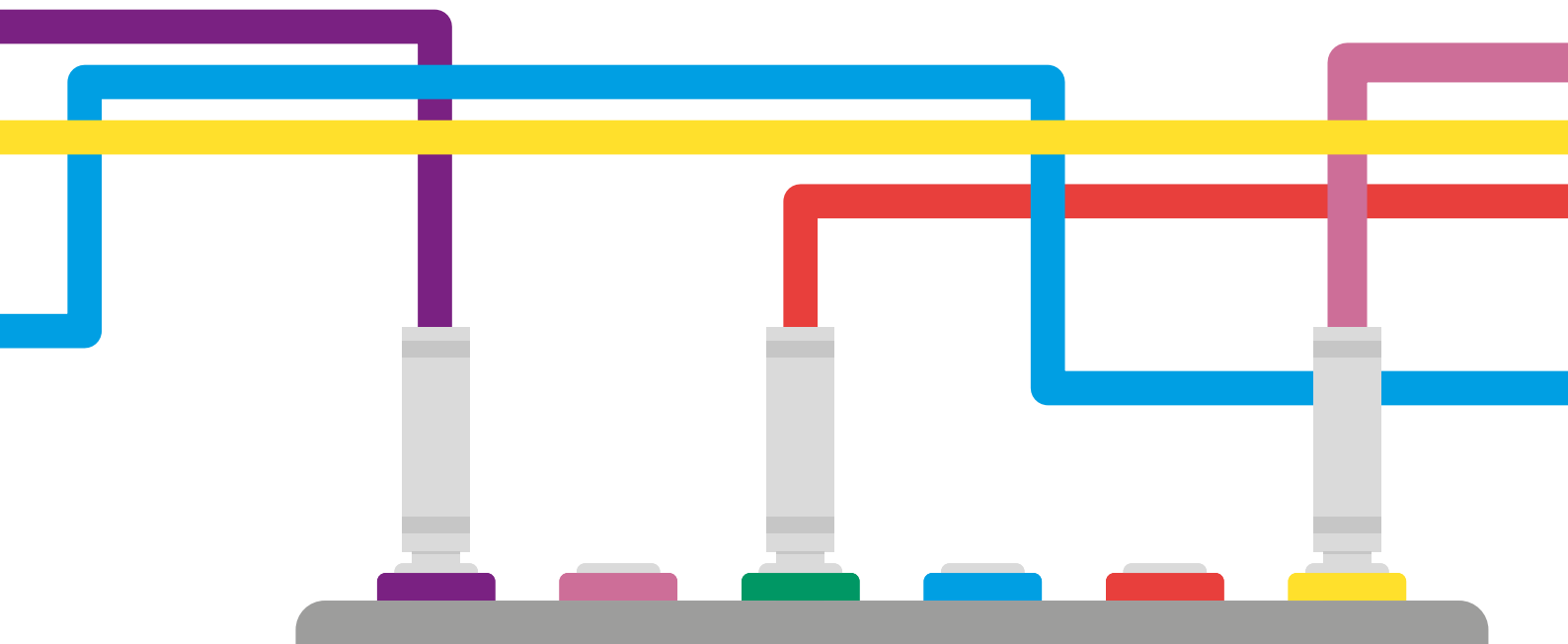
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It's not easy being a teen



Words
Louise Walsh

Our final article on the developing brain focuses on the workings of the teenage mind. By understanding how the adolescent brain wires and rewires, scientists are helping to pinpoint why teenagers are especially vulnerable to mental health problems – and why some are resilient.

When Charly Cox was diagnosed in her teenage years with depression and other mental health disorders, what lay ahead for her was “a long and painful ordeal of trial and error, guesswork and delay. I felt loss and frustration more times than I was ever gifted hope, knowledge or effective treatment.”

For Flo Sharman, who suffered from mental illness from the age of eight: “I lost my childhood to the stigma surrounding mental health.”

James Downs recovered from disordered eating and extreme emotions, but he describes the process as being “like an experimental DIY project rather than something with clear oversight and a plan.”

One in four of us experience the debilitating, isolating and traumatic effects of mental health disorders. Around 75% of adult mental health problems begin before the age of 18, disrupting education and social interactions, affecting relationships with family and friends and future job opportunities, and in some cases, costing lives.

Charly, Flo and James are among those who have lent their support – and their stories – to the mental health charity MQ to help work towards a future in which adolescents no longer face the life-altering challenge of living with these disorders.

Dr Anne-Laura van Harmelen from Cambridge's Department of Psychiatry leads a project funded by MQ, called

HOPES, and shares this vision: “Our brains undergo complex neural development during the teenage years to prepare us to take care of ourselves. However, some of these changes may be linked to a vulnerability to mental health disorders. If we can better understand what these vulnerabilities are, we can identify those at risk and treat them early, before the disorders emerge.”

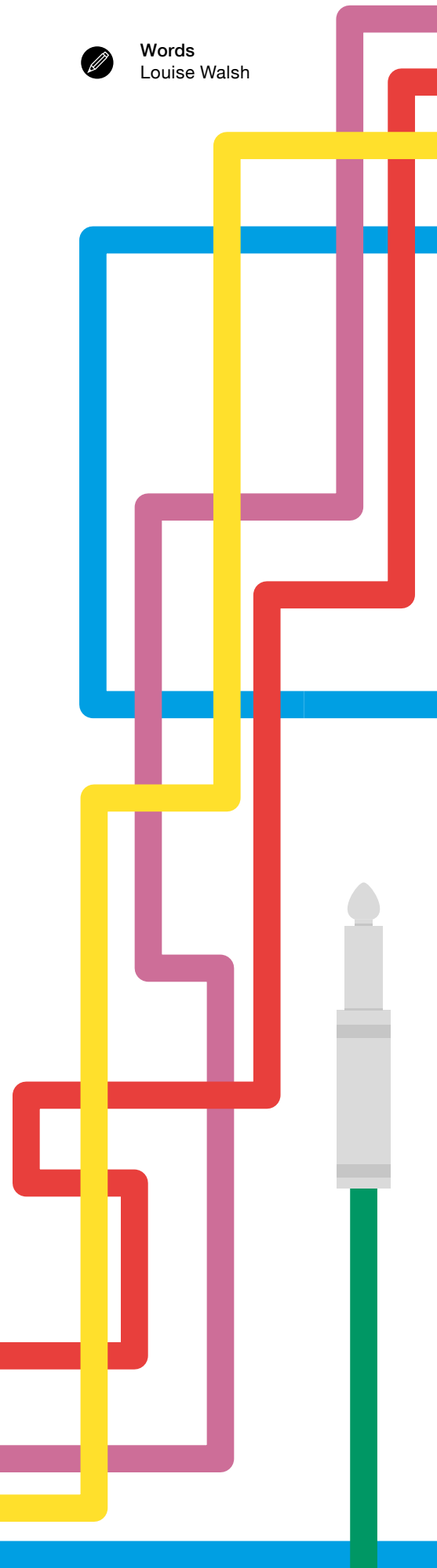
But, until recently, remarkably little has been known about what's going on inside a teenager's head. Unravelling some of the complexity has required the combined input of psychiatrists, neuroscientists, psychologists, social scientists, computational biologists and statisticians – and the brains of hundreds of healthy

75% of adult mental health problems begin before the age of 18

teenage volunteers. The teenagers were scanned as part of the NeuroScience in Psychiatry Network (NSPN), set up in 2012 by Professor Ian Goodyer from the Department of Psychiatry with funding from the Wellcome Trust.

So far, 2,300 healthy volunteers aged 14 to 24 years have been recruited by the University of Cambridge and University College London for analysis through behavioural questionnaires, cognitive tests, and medical and socio-economic history. Some 300 adolescents have also had their brain anatomy and activity scanned millimetre by millimetre using MRI, a method that can reveal connections between brain activity centres.

The result is one of the most comprehensive ‘circuit diagrams’ of the teenage brain ever attempted. “The project has been a big step forward in looking



inside the black box of the teenage brain,” explains Professor Ed Bullmore, who leads the NSPN. “We found that there were distinctive patterns of developmental change in brain structure and function during adolescence that could help to explain why mental health disorders often arise during late adolescence.”

For instance, Bullmore’s colleagues Dr Kirstie Whitaker and Dr Petra Vértés discovered that the outer region of the brain, known as cortical grey matter, shrinks, becoming thinner during adolescence. As this happens, the levels of myelin – the sheath that ‘insulates’ nerve fibres, allowing the fibres to communicate efficiently in the white matter – increase.

In a separate study, Dr František Váša designed a method to combine all of the scans of the structural changes in the brain through a ‘sliding window’ – as if viewing the changes in the brain network of an ‘average’ adolescent as they mature from 14 to 24 years of age. It sounds simple enough but this innovation was so complex that it took several years of statistical and computational analysis to perfect.

“We saw that the changes are greatest in the most connected ‘hub’ parts of the brain. Our interpretation is that when the brain develops it builds too many connections; then, during the teenage years, those that are used frequently are strengthened and others are ‘pruned,’” says Váša, whose PhD studies were funded by the Gates Cambridge Trust.

What makes this especially interesting is that Vértés and Whitaker also discovered that the brain areas undergoing the greatest structural changes during adolescence are those in which genes linked to risk of mental health disorders are most strongly expressed.

One of the disorders is schizophrenia, which affects 1% of the population and often starts in adolescence or early adult life. Vértés has recently been funded by MQ to search for unique patterns of brain connectivity among those who develop symptoms of schizophrenia, and to cross-reference them with patterns of gene expression across the brain. “Not only is this knowledge important for identifying new treatments that are more effective for a greater number of patients at an earlier

stage, but it could also help in predicting those who are at risk,” she explains.

Another area where there has been little improvement in predicting behaviours is that of suicide – the second leading cause of death among the young.

“Around 16% of teens think about suicide and 8% report making an attempt, yet there has been little improvement in our ability to predict suicidal behaviours in 50 years,” says van Harmelen, who is a Royal Society Dorothy Hodgkin fellow. The HOPES project she leads aims to develop a model to predict who is at risk of suicide by analysing brain scans and data on suicidal behaviour of young people from across the world to identify specific, universal risk factors.

“These risk factors may be connected with traumatic and stressful events early in their lives,” she adds. “In fact, we know that about a third of all mental health problems are attributable to events such as bullying, abuse and neglect. Much of my work has been to understand the impact of these factors on the developing brain.”

She discovered that childhood adversity is related to an altering of the structure and function of parts of the brain, and that this increases vulnerability to mental health problems. Intriguingly, some adolescents with traumatic early life experiences fared a lot better than would be predicted. This ‘resilience’ was enhanced by receiving the right kind of support at the right time. She calls this ‘social buffering’ and finds that for 14-year-olds it most often comes from family members, and for 19-year-olds from friendships.

With funding from the Royal Society, she is now starting to look for biological factors that underpin resilient functioning – for instance, how does the immune system interact with the brain during periods of psychosocial stress in resilient adolescents? Are there biomarkers that can be used to predict resilience after childhood adversity?

“We are diving deeper into the factors and mechanisms that might help,” says van Harmelen. “We know there are lots of social, emotional and behavioural factors that help to build resilience, and that these factors are amenable to

intervention by therapists – but which are the most important, or is it a specific combination of these factors?”

“If you speak to anyone who has had a mental health problem, you will know the effect it’s had on them and their families,” she adds. “Even a minor contribution to lowering this effect through early diagnosis and treatment is worth a lot of effort.”



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CHILDREN OF THE CITY

Tackling violence in the 21st century

Up to one billion children worldwide are estimated to be victims of violence. Now, an intended study of 12,000 children in eight cities worldwide wants to discover what it really means to be a child of the city today – the adversities, the vulnerabilities, the resilience.

It's 1960 and two boys are born into cities of different nations about to gain independence from the British. Their homelands have comparable GDP per capita, similar literacy rates and roughly the same levels of crime and violence.

Now nearing 60 years old, they are about to have grandsons of their own. The grandson born in Kingston, Jamaica, will have a startling 15% chance of growing up to be a victim of homicide, if current murder rates continue. The grandson born in Singapore will have less than a 0.1% risk of violent death.

How did these countries diverge over a single lifetime until they were at opposite ends of the spectrum of violence? Some blame politics, while others point to drug trade exposure or differences in crime prevention and health policies.

State legitimacy waxes and wanes, illegal markets bubble and burst, neighbourhoods thrive or deteriorate – and all these fluctuations trickle down to entrench order or violence in millions of lives from childhood onwards. Yet we know little about how this happens.

“Experiences in the first years of life shape a person’s lifelong development,” says Manuel Eisner, Wolfson Professor at Cambridge’s Institute of Criminology. “If we want to understand the roots of adversity that lead a nation to violence and turmoil, we need to understand how it incubates in a child of that society.

“For example, what does a child in Kingston experience – even before birth – that may increase the risk of failure at school, or mental and physical health problems, or criminality and substance use? How does that compare with children in the cities of South Africa, or East Asia?”

Eisner argues that everything from national and municipal systems, such as infrastructure and education, to proximal

environments – the street, family and even uterus – contribute to the “psychosocial construction” of children, and consequently the stability of societies in which those children become citizens.

His goal is to map the risk factors that influence early child development around the world, from the political to the hormonal. To do this, Eisner and his colleagues on the Evidence for Better Lives Study (EBLS) intend to follow 12,000 children yet to be born in eight cities in Jamaica, Ghana, South Africa, Romania, Pakistan, Sri Lanka, Vietnam and the Philippines.

Children will be tracked from the womb through the first 1,000 days of life, and hopefully on to adolescence, in a major birth cohort study that Eisner wants to see become a valuable resource for “understanding and promoting child wellbeing in the 21st century”. The ambition is to identify how policy can most effectively stem societal violence and “foster resilience”.

“For the first time in history, there are goals at a global level aimed at reducing child abuse, exploitation and all forms of violence, and to promote children’s mental health,” says Eisner, describing the United Nation’s 2030 Sustainable Development Goals. “The EBLS is our response to this challenge. It will provide important evidence for system-level changes to tackling violence against children. But it can also shine light on how violence evolves.

“If we want to address high levels of violence in a city like Kingston, we need to know the ages when active ingredients are added to young people’s development. Then we can design the right intervention strategies.”

There is a significant knowledge gap when it comes to violence and its causes. While numerous studies have taken place in Europe and the USA, research in the Global South – where violence is endemic in many countries – is severely lacking.

The eight mid-sized cities have been chosen to reflect the diversity of social and cultural conditions across the world, explains Eisner. For example: Koforidua in Ghana, a regionally important city in a country where harsh physical discipline

of children is standard; and Tarlai Kalan, about 10 km outside Islamabad in Pakistan, a nation where half of women are thought to be victims of domestic violence.

Other cities include Stellenbosch in South Africa, where the legacy of apartheid looms large; the city of Hue, site of one of the Vietnam War’s bloodiest battles and now a growing commercial centre; and Kingston, a city plagued by gang culture.

The study will be managed by a team of 15 co-investigators, including Professor Claire Hughes from the University’s Centre for Family Research (see p. 32) plus other experts in psychology, sociology, paediatrics, nutrition, public health and criminology, and coordinators from research institutions in each of the eight cities.

“We want to bring together different layers of explanation from social structures like gender inequality and trust in public institutions to the ways in which exposure to violence affects brain development even before the child is born, so interdisciplinary research is essential,” says Eisner.



“By comparing a new generation from each city, we can build a scientific backbone for interventions to prevent violence against children, and boost child wellbeing initiatives that work in different global contexts.”

Scoping for the study began in late 2015, and 2018 saw the start of a pilot version of EBLS, funded by Fondation Botnar, involving 1,200 families across the eight sites. The team is now aiming to secure funds for a ten-fold participant increase.

In November 2018, policy figures from all the study cities will meet for a summit in Manila in the Philippines, enabling the project to build policy involvement and impact into the study from the onset. They will also visit Valenzuela – another of the eight cities – along with representatives from supporting organisations including UNICEF and the World Health Organization (WHO).

The scale of ambition for the project is vast says Eisner. From health and housing services to transport links, the study will

take in a wide range of public policy and its effects on expectant mothers and then their children. Researchers will also build a picture of immediate environments, initially in utero – from stress hormones to substance use.

“Is the mother supported or treated violently by family? Does she lie awake listening to gunshots in the street outside? How many buses does she need to take to get to the health clinic? Tragically, some children have been exposed to violence and drugs before they are even born.”

Importantly, the EBLS team is determined to include fathers as much as possible. “Male role models are often missing from studies such as this; this project provides an opportunity to gather data to fill this gap.”

A variety of innovative approaches are being discussed such as the use of microphone vests to pick up levels of hostility in ambient noise around children, and games using puppets to gauge the early development of a sense of fairness and justice.

When he established the Violence Research Centre at Cambridge in 2014, Eisner held a joint conference with the WHO based on the bold declaration that worldwide violence can be reduced by 50% in the next 30 years. With up to a billion children estimated to be victims of violence each year, the task is daunting. However, Eisner’s previous work on long-term trends over centuries reveals a dramatic decline in violence across human history.

“Halving violence is a legitimate aim for a criminologist. And yes, the police and justice systems are integral to that. But we need to get to the source, and see how macro-level decisions translate into resilience or adversity for the youngest in our global society,” he says.



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Words
Fred Lewsey



Here to change *the world*



There is far more than just an outstanding Ofsted rating that sets the University of Cambridge Primary School apart: it places research at its heart, in both informing education practice and in furthering research at Cambridge's Faculty of Education and elsewhere.

Visitors walking through one of the 'learning streets' that run through the core of the University of Cambridge Primary School (UCPS) soon notice something unusual. It's not the fact that they end up back where they started – the school's Polo-mint-shaped structure is just one of its radical features – but the startling lack of doors: classrooms open up invitingly on each side of the street, with snatches of lessons, storytelling or music audible within.

The open-plan design both facilitates and symbolises the school's role as the first, and still only, University Training School at primary level in the UK (the only secondary UTS is in Birmingham). Sponsored by the University of Cambridge, its role is to provide brilliant and inclusive primary education for its local community, and also to work alongside the University's Faculty of Education and others to be research informed and research generating.

Children are learning here – and indeed the school has just been judged outstanding in a glowing first Ofsted inspection – but so too are teachers, researchers and visitors coming from as far afield as Australia, India and China to observe the innovative practice on display.

Now receiving its fourth intake of children, UCPS was pioneering from the start. Built to serve the emerging settlement of Eddington developed by the University in North West Cambridge, the school was able similarly to build its values and curriculum from the ground up. An educational 'dream team' of world experts in a variety of specialisms, based at Cambridge's Faculty of Education, provided input: among them, Professor Robin Alexander, Director of the groundbreaking Cambridge Primary Review; Dr Kathy Burke, an expert in the relationship of spaces to learning; creativities specialist Professor Pam Burnard; Emeritus Professor Neil Mercer, a leader in classroom language research; and play expert Dr David Whitebread.

The striking circular design emerging from the fenland earth was the first sign of the school's research-based practice. The open central courtyard, nodding to the Cambridge college courts, offers children the safety of enclosure, while covered gaps in the ring of the building provide a vista through the school to the wider world beyond. Inside, meanwhile,

break-out areas and cushioned spaces to climb into and curl up with a book reflect the love for soft surfaces and secret places expressed by children when adults – like Burke – take the time to ask them.

The UCPS curriculum, illustrated with a colourful circular diagram on the office wall of Headteacher Dr James Biddulph, reflects the same powerful research influence.

"Ours is a values-led curriculum," says Biddulph, grabbing a short break before driving the school minibus for a Year Four trip. "Lots of schools have values posters on their walls but sometimes they are not talked about and adults don't model the values. We have a curriculum that explicitly talks about values and gives examples of what it means to be compassionate active citizens, for example."

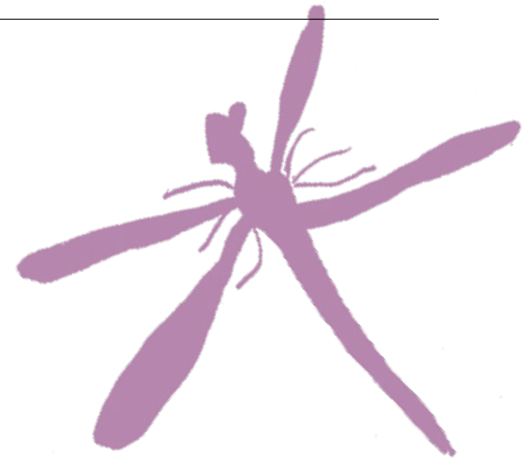
Drawing on a wide range of research (the curriculum design statement on the school website lists 65 separate references, including the Cambridge Primary Review), Biddulph and his team set out to devise an educational curriculum that was about far more than content alone.

"It might seem clichéd but surely the reason we're here, as educators, is to change the world"

"As well as asking 'what knowledge will be taught?', we asked 'what will be the outcomes for children beyond grades and exam results' and 'how will they be as humans?'" says Biddulph, who did his own PhD on creative learning at the Faculty.

While UCPS, as a free school, does not have to adhere to the National Curriculum, pupils do have to sit the UK's national tests, known as SATs. However, SATs do not drive the school's vision, the Head adds. "We look longitudinally. For example, in relation to reading, we ask 'what do we want our young children to be like as readers at 30?', and then we reach backwards. We don't just say 'they leave us in Year Six': we say 'how do we inspire them to be readers, thinkers and writers?'"

Building from the work of the Faculty of Education, the school identified three 'golden threads' that bind together its curriculum: habits of mind (the resilience and problem-solving skills that help children learn); dialogue (exemplified in the new DIALLS project – see next article); and playful inquiry. The aim, looking forward



again, is to "empower children to make sense of the complex world in which they live" and nurture "compassionate citizens who want to make a positive contribution to their local and global worlds."

With research as familiar a concept as playtime in UCPS, children are already contributing to the learning of others. In 2016 – only its second year in operation – the school welcomed Cambridge Architecture undergraduates, who designed play structures in conjunction with Year Three pupils ("The children gave very detailed feedback to the students: it was like *Dragons' Den*," notes Biddulph).

Students taking the BA in Education now visit UCPS as they study for a new research module devised by Professor Geoff Hayward, observing and talking to pupils as they examine how the school's values are lived out in reality. Connections are being built with local schools and, in January 2018, UCPS became a regional hub for the Chartered College of Teaching.

One of the most significant projects to date, led by Burnard, explored how the arts can contribute to transdisciplinary learning – turning STEM subjects (science, technology, engineering and maths) into STE(A)M. Six bronze sculptures – a child representing each of five continents and a baby penguin to symbolise Antarctica – were placed in different settings within the school. The installation acted as a stimulus for children to explore the importance of water in a changing world, making seamless connections between art and mathematics and music as they did so, and focusing on the world of the future as a place they could create rather than simply inherit.

"Children are not separating subjects – they're seeing the connection between them," says Burnard. "It's a transdisciplinary approach to teaching and learning which has a lot of global interest. This school is not reacting: it's proactive around the issues arising around 21st-century crises – of creativity, inclusivity, environment."

Such experiments, while cutting edge, might seem well out of reach for many schools lacking the privileged connections

of UCPS, Biddulph acknowledges, though he points out that the pupil mix is wider than many might assume. “This is not the University’s school for the children of academics, but a community school on the edge of Cambridge.”

Nevertheless, the Head is unapologetic in searching for a “new narrative in education” that challenges, for example, the model of schools such as the Michaela free school in Brent, North London, billed as the “strictest school in Britain” with a “no excuses” approach to discipline.

“There are lots of schools popping up like that. We want to be a new voice in the chorus. It might seem clichéd but surely the reason we’re here, as educators, is to change the world.”

Burnard agrees that the school has a unique position – with correspondingly significant power to influence. “There is a powerful trio of research, theory and practice – which in turn influences policymaking. They’re not separate – they’re inextricably interconnected and performed as a united unit, and that’s something the government has been wanting to see. They come together in the living practices of releasing imagination in this school, where experts, practitioners and researchers from the Faculty of Education are not just in the distance as a shadow but coming and going daily.”

A draft new vision statement for UCPS boldly says: “The University of Cambridge Primary School is committed to improving education for all primary children, everywhere.”

“The world is watching us,” says Burnard. “The world is watching this school.”

We are all ‘others’



As the world around us increasingly divides into ‘us and others’, the University of Cambridge Primary School is taking part in a new research project to help children discover for themselves that far more unites us than divides us.

At times of dramatic change and conflict, words can become weapons. Europe is transforming: migration, economic crises and Brexit are shaking the continent’s sense of identity, and debate has turned quickly to division and misunderstanding, to angry Twitter exchanges and pumped-up political stand-offs.

Now, a new Europe-wide project led by Cambridge’s Faculty of Education and closely linked to the University of Cambridge Primary School (UCPS) is encouraging better dialogue – by initially removing language altogether.

The three-year DIALLS project (Dialogue and Argumentation for Cultural Literacy Learning in Schools) will use wordless picturebooks and short films as a stimulus for discussion by children in primary and secondary schools. Exploring their individual and collective responses to the texts within school – and with peers in partner countries from Portugal and Cyprus to Israel and Lithuania – will, researchers believe, help children understand their own cultural identities, while also recognising and respecting those of others in a fast-changing and diverse Europe.

the goal is not to find cosy solutions to the world’s problems, but to give children more tools to manage difference positively

“Our approach is to use the skills of dialogue to promote understanding,” says Dr Fiona Maine, a visual literacy specialist and principal investigator for the €4.4 million project, funded by the European Union Horizon 2020 programme and involving nine universities. “To have an effective dialogue, you need to understand other people’s perspectives and where they are coming from, and perhaps critique your own views.”

Texts without words, needing no translation across borders, are an ideal stimulant for cross-cultural debate, Maine says. “These texts are ambiguous, and so give rich opportunities for discussion.”

A preliminary collection of dozens of materials gathered from across Europe since the project’s launch in May 2018 reflects the fact that many picturebooks have resonance for readers of all ages. *The Mediterranean*, by the



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Swiss illustrator Armin Greder, is for older readers and tackles themes of displacement and violence, its beautiful charcoal images confronting the tragic reality of refugees lost at sea. *Baboon on the Moon*, directed by Christopher Duriez, is a quirky animated film in which a baboon is taken from the jungle to top up the moon's light each day. At first glance, it's more playful, yet it addresses similarly powerful notions of home and belonging that could be discussed by all ages.

The next task is to whittle the initial selection down to a core set of 45 texts, likely to include some 30 books, with films and potentially artworks making up the total. It is here that children will themselves get involved in the research, with pupils at UCPS – the UK hub for the project – reviewing and choosing alongside their teachers.

“Student voice is important in the selection,” says Maine. “We’ll ask children which they like, but also which they feel give them real opportunities for discussion.”

The chosen texts, divided for different age groups where appropriate, will then be used by partner schools in each of the nine participant countries to stimulate discussion over 15 lesson sequences. The aim is twofold: children in 300 classes across Europe will explore their responses to the ideas prompted by the books and films, but in doing so will also develop their skills in dialogue and argumentation (the structuring of discussion by hearing and building on others’ points of view). These, in turn, underpin the fundamental goal of the project: to develop children’s “cultural literacy” – not in the sense of knowledge of a defined European culture of art and literature, but in an openness to engage with many different interpretations of it.

“For effective dialogue, in essence, you have to be tolerant, empathetic and inclusive of other positions,” says Maine. “Cultural literacy is not about accessing culture, but about a disposition to engage. Through understanding your own heritage, cultural identity and values and how they are positioned, you are better

able to see that actually everybody has a slightly different experience. So it is not about saying ‘us and others’: we are all ‘others’.”

Children’s exploration of this ‘otherness’ will begin in the classroom as they discuss texts with fellow pupils, moving on as the project develops to discussions with children elsewhere in their own country (in England, 30 schools will be involved at first, with more in the third year once resources on using the texts are online).

Children across Europe will be able to share their ideas using a specially created digital platform. One landmark will be a semi-virtual conference in May 2020 bringing together school students to share ideas on the themes explored in the wordless texts, leading to the creation of a “manifesto for cultural literacy for young people in Europe” to sit alongside a set of freely available resources for teachers.

Along the way, children will also develop their own ‘cultural artefacts’ – artwork, stories or short films to be made publicly available in a virtual gallery. In the UK, participating teachers will have access to the Faculty of Education for professional development.

For UCPS, with its close ties to the Faculty and strong research mission, the DIALLS project sits perfectly with its own curriculum priorities. “The real

key perhaps to the project is to connect teachers and academics and children, and doing that through different texts,” says UCPS Headteacher Dr James Biddulph. “It fits in with our school’s focus on developing compassionate citizens who are actively involved in their world.”

But with its pan-European scope and ambition to promote understanding, is there a risk the DIALLS initiative could seem unduly idealistic in an era of transition, enormous complexity and debates that can seem so intractable that many in the adult world are tempted to turn away and tune out? How can we expect children to make sense of Europe and its different – and changing – cultures, when even we adults frequently seem unable to do so?

For Maine, the goal is not to find cosy solutions to the world’s problems, but to give children more tools to manage difference positively. “This isn’t about finding answers – we aren’t trying to get people to agree, nor even to seek to agree. This is about listening and understanding. It’s about a way of being.”



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Words
Lucy Ward



Gardeners

The 'skill' of parenting

Wanting your child to have the best chance in life is natural for any parent. But by focusing too much on the 'skill' of parenting, are we losing sight of things that matter more – how we talk to and play with children? Cambridge researchers are examining how parents can best help their children in their early years through nurturing rather than shaping.

Professors Claire Hughes and Paul Ramchandani have spent their adult lives studying children. Both are fascinated by the complicated jigsaw of early child development. "Such a lot happens in pregnancy and the first few years of life: the child's brain and physical development, the acquisition of new skills and knowledge, it's utterly transforming," says Ramchandani, Cambridge's first LEGO Professor of Play.

But while we know much about what goes on, we understand far less about how the outside world shapes this transformation – knowledge we need as parents, practitioners and policymakers to provide environments that help children thrive.

It's clear, for instance, that our mothers, fathers and families affect our lives and the people we become, but has understanding the importance of parent-child relationships led to modern-day parenting approaches that stifle rather than help a child to flourish?

"Think carpenters and gardeners," says Hughes, referring to a book by American psychologist Alison Gopnik published in 2016. "Gopnik's theory is that parents who behave like carpenters mould their child by a deliberate, organised and focused influence on their development; those who behave like gardeners create a safe, nurtured and free environment that helps their child to shape themselves."

Hughes' work looks at how parents talk to children in their early years and what this means for how children develop some of the most crucial skills of their lives. Since she began her academic career as an undergraduate in Cambridge 30 years ago, her focus has shifted from clinical groups, including children with autism, to studying social influences on two key psychological constructs – theory of mind and executive function.

Psychologists use the term theory of mind, or mind reading, to describe awareness that other people have thoughts, feelings, intentions and desires. Most children develop theory of mind around the age of four. "Without it you can't joke, you can't lie, you can't get sarcasm – the many social things that hinge on what others say and mean to say," she says.

As a result, theory of mind is pivotal to children's ability to interact and form social relationships, but it doesn't act alone. Along with theory of mind comes executive function – all those higher-order thinking skills such as planning, adapting plans when situations change and working memory.

"These two things go hand in glove," explains Hughes, whose research is funded by the Economic and Social Research Council. "You need good executive function to acquire a theory of mind, because how we process information from others depends on being able to keep track of information and shift attention, and we

know that poor executive function often leads to behavioural problems, which can in turn affect children's ability to learn from social situations."

By following a group of 117 children from toddlerhood to adolescence, and developing a new battery of tests – including an innovative 'silent film' task based on Harold Lloyd's 1923 comedy *Safety Last!*, developed with one of her former students, Dr Rory Devine – Hughes has been able to gain a deeper understanding of how family environments shape young children's theory of mind.

Her studies show that how parents talk to toddlers – in particular the extent to which they use words such as 'think', 'believe', 'understand' and other so-called 'mental state talk' – predicts how well children do at the silent film task when they reach the age of ten.

One of her new studies, which involves more than 400 first-time families in the UK, USA and Netherlands, aims to tease out differences in the way that fathers and mothers talk to their children. "We're filming children at home at four, 12 and 24 months and we are now following them up at nursery at the age of three," says Hughes. "It's a big study, producing very rich data, and we're using some interesting





& Carpenters

“Those who behave like gardeners create a safe, nurtured and free environment that helps their child to shape themselves”

Since then, he’s studied the way fathers play with their babies and found that when fathers were more physically and emotionally engaged, children did better behaviourally and cognitively. “It’s striking to see how different fathers can have very different styles of interacting with their babies, even though they are very young, with some getting stuck in and leading the play, and others watching and following their child’s lead more”.

Ramchandani is Director of Cambridge’s Centre for Research on Play in Education, Development and Learning, and with the team will be looking at an even wider field of play – studying its role in learning and social development, and finding the best way of measuring playfulness itself.

“Healthy child development is a fascinating and complicated picture: a jigsaw comprising fathers, mothers, siblings and the wider world, and involving language, play, physical and psychological health and more,” adds Ramchandani. “By getting a clearer picture of how it works, we have the best chance of helping to improve children’s lives around the world.”

Testing new interventions is also central to Ramchandani’s research, not least because as well as an academic he’s also a practising psychiatrist. “I come from a medical background where you want to learn stuff so that you can do something about it,” he says.

He’s currently leading a randomised controlled trial with parents from London, Peterborough, Oxford and Hertfordshire to see if video feedback is a viable way of promoting positive child development. Over six sessions, parents are filmed playing with their toddler and the videos are then used to help parents notice – and respond appropriately to – their child’s communication.

One of his long-standing areas of interest is the role fathers play in the lives of their young children, something he feels has often been overlooked. “There are obvious reasons for this – mothers are more often the primary carers and theories that have dominated psychology have revolved around the mother–child relationship – plus, over the past 30 years, most research on children’s relationships with parents has focused on mothers,” says Ramchandani.

Before arriving in Cambridge in early 2018, he conducted the first major study of depression in fathers, which revealed that paternal – as well as maternal – depression has an impact on child outcomes.

“This study got me thinking about the family constellation, about how mothers and fathers influence children, and how children influence parents too, which led to my interest in play as one aspect of those relationships.”


technology – including a device that’s like a talk pedometer – to get at children’s linguistic environments.”

Such detailed, long-term studies could, she hopes, lead to simple and effective tools to help parents foster their children’s theory of mind skills. Together with Professors Lynne Murray and Peter Cooper at the University of Reading, Hughes is testing a South African intervention based on reading picture books, something that’s on the decline within UK families.

“It’s been a revelation to me to see how hard some parents find it to read a picture book. Some literally just read what’s on the page, and if there are no words they just show the picture,” she says. “The South African study shows that in ten weeks you can take parents who aren’t very good at this type of reading and show them how to get their child involved.”

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 **Words**
Becky Allen

How could multilingualism benefit India's poorest schoolchildren?

Multilingualism is the norm in India. But rather than enjoying the cognitive and learning advantages seen in multilingual children in the Global North, Indian children show low levels of learning basic school skills. Professor Ianthi Tsimpli is trying to disentangle the causes of this paradox.

The crowded and bustling streets of Delhi teem with life. Stop to listen and, above the din of rickshaws, taxis and buses, you'll hear a multitude of languages, as more than 20 million men, women and children go about their daily lives.

Many were born and raised there, and many millions more have made India's capital their home, having moved from surrounding neighbourhoods, cities and states or across the country, often in search of a better job, a better home and a better life.

Some arrive speaking fluent Hindi, the dominant language in Delhi (and the official language of government), but many arrive speaking any number of India's

22 officially recognised languages, let alone the hundreds of regional and tribal languages in a country of more than 1.3 billion people.

Around 950 miles south of Delhi lies Hyderabad, where more than 70% of its seven million people speak Telugu. Meanwhile, in Bihar, in the northeast of India, Urdu has replaced Hindi as the dominant language across this poor and populous state of more than 100 million people.

What links Delhi, Hyderabad and Bihar is a four-year project, *Multilingualism and multiliteracy: raising learning outcomes in challenging contexts in primary schools across India*, funded by the Economic and Social Research Council and the Department for International Development. Led by Professor Ianthi Tsimpli, from the Department of Theoretical and Applied Linguistics, the project involves Dr Dénes Szucs from the Department of Psychology, plus researchers from the University of Reading and project partners in Karnataka, Hyderabad and New Delhi.

The overriding aim of the project is to find out why in a country where multilingualism is so common (more than 255 million people in India speak at least two languages, and nearly 90 million speak three or more languages), the benefits and advantages of speaking more than one language, observed in Europe for instance, do not apply to many of India's schoolchildren.

For Tsimpli, the answers to this conundrum may lie within the dataset she and her colleagues are compiling with the help of more than 1,000 primary-age schoolchildren across Delhi, Hyderabad and Bihar.

"Each year across India, 600,000 children are tested, and year after year more than half of children in Standard 5 [ten-year-olds] cannot read a Standard 2 [seven-year-olds] task fluently, and nearly half of them could not solve a Standard 2 subtraction task," says Tsimpli, who co-leads Cambridge Language Sciences, the University's Interdisciplinary Research Centre that brings together researchers from different fields to tackle 'grand challenges' where language is a factor.

"Low literacy and numeracy limit other important capabilities, including critical thinking and problem solving. Low educational achievement can lead to many dropping out of school – a problem disproportionately affecting female students. And the gap between state schools and private schools increases every year."

She and colleagues are looking at whether these low learning outcomes could be a by-product of an Indian school system whereby the language that children are taught in often differs from the language used at home.

"We are looking at eight to 11-year-old schoolchildren in rural and urban areas," she explains. "Within those urban areas we make the distinction between boys and girls living in slum and non-slum areas."

"Many children are internal migrants who move from remote, rural areas to urban areas. They are so poor they have to live in slums and, as a result of migration, these children may speak languages that are different to the regional language."

"By looking at the mismatch between home and school languages, and by using tests and other socio-economic and educational variables, we try to find out whether these children are advantaged or disadvantaged in literacy, numeracy, mathematical reasoning, problem solving and cognitive skills."

Two years into the four-year project, the team has discovered considerable variation in the provision of education across government schools in the three areas, with different teaching practices and standards.

Having tested all 1,000 children, they will now embark on retesting them, looking not only at test results, but also allowing for other variables such as the standard of schooling, the environment and the teaching practices themselves. It's possible that one of the causes of low performance is the lack of pupil-centred teaching methods; instead, the teacher dominates and there is little room for independent learning.

Although the findings are at a preliminary stage, Tsimpli and her team have found that the medium of instruction used in schools, especially English, may

Urdu





Credit: Ianthi Tsimpli

contact with the numeracy skills essential for day-to-day survival.

Tsimpli adds that, despite the project only being at its midpoint, it has already caught the attention of government ministers, including Delhi's Minister for Education, who is keen to use their findings to inform and adjust school policy in India's capital city and the wider state.

"Delhi may be keen to adopt root-and-branch reform if our findings support it," explains Tsimpli. "They are as keen as us to understand how the challenging context of deprivation can be attenuated when focusing on the languages children learn and use while at school.

"Our findings don't mean that you're doomed if you're poor. It may be that these low learning outcomes are because of the way education is provided in India, with a huge focus on Hindi and English as the mediums of instruction, to the potential detriment of children unfamiliar with those languages.

Punjabi

ਪੰਜਾਬੀ
ਪੰਜਾਬੀ

hold back those children who have little familiarity with, or exposure to, the language before starting school and outside of school life.

"Most of the evidence from this and other projects shows that English instruction in very disadvantaged areas

Telugu

తెలుగు

might not be the best way to start, at least in the first three years [Standards 1 to 3] of primary," says Tsimpli.

"What we would recommend for everyone, not just low socio-economic status children, would be to start learning in the language they feel comfortable learning in. The medium of instruction should reflect the strengths of the child. When it does, that child will learn better. English can still

be used, but perhaps not as the medium of instruction in primary schools. It could, for example, be one of the subjects that are being taught alongside other subjects, starting perhaps from the third year of primary school.

"We are not suggesting that English be withdrawn – that ship has sailed – but we perhaps have to think more about learner needs. There is perhaps too much uniformity in teaching and less tailoring to the children's language abilities and needs."

While the preliminary results show that there is no difference in general intelligence among boys and girls from slum versus urban poor backgrounds, a surprising finding has been that children from slum backgrounds in Delhi do not seem to lag behind other children from other urban poor backgrounds – and in some cases perform better (e.g. in numeracy and literacy tasks).

This unexpected finding may be down to the life experiences of children growing up in slums, where they are likely to mature faster and come into closer

"Language is central to the way knowledge is transferred – so the medium of instruction is obviously hugely influential. We hope to be able to show that problem solving, numeracy and literacy can and do improve in children who are educated in a language of instruction that they know. The trick may be to bridge school skills with life skills and make use of the richness of a child's life experience to help them learn in the most effective ways possible."



Words
Stuart Roberts



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Credit: Robert Macfarlane and Jackie Morris, *The Lost Words* (2017), Hamish Hamilton



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*Once upon a time,
words began to vanish
from the language of
children...*

The *Lost Words* by Robert Macfarlane and Jackie Morris summons the magic of nature to help children find, love and protect the natural world; numerous crowdfunding campaigns later, the book is appearing in primary schools all across the UK.

First there was the finding that British primary school children were more at ease naming their favourite Pokémon character than they were at naming a hare, a deer or an oak tree.

Then there were the revisions to a new edition of the *Oxford Junior Dictionary* (OJD): out went everyday nature words like acorn, bluebell and kingfisher, no longer used enough by children to merit inclusion; in came attachment, broadband, voice-mail, reflecting today's tech-savvy child who is more at home on the internet than they are in the woods.

Fascinated and concerned by these changes, Dr Robert Macfarlane began to wonder about the relationship between childhood and the living world.

"What we might call the 'nature of childhood' has changed dramatically in Britain over recent decades," says Macfarlane, a Reader in Environmental Humanities in the Faculty of English. "Online culture has boomed, screen time has soared and the 'roaming range' within which children can play and stray unsupervised has shrunk by more than 90% in 40 years amid parental fears about traffic, 'stranger danger' and the pressure of school work."

After Macfarlane read the 'Pokémon paper' (a study published in *Science* in 2002 by Professor Andrew Balmford from Cambridge's Department of Zoology), he started to gather other evidence of a loss of 'nature-literacy'. A National Trust (NT) survey, for instance, showed that half of children couldn't tell the difference between a wasp and a bee, yet almost all could name a Dalek; and a three-year RSPB research project found only one in five children in Britain are 'positively connected to nature'.

To wish for the restoration of this 'positive connection' is not to lament a "lost golden age of barefoot childhood", says Macfarlane, or to favour nature to the exclusion of technology, "rather it is to engage with much broader inequalities within society, and to seek to increase both what is good for nature and what is good for children."

A report by the NT on Natural Childhood in 2012 set out compelling evidence that a decline in childhood wellbeing and mental health and an increase in obesity rates are just some of the costs of a generational decline in having freedom outdoors.

The NT report also said: "It is not just children who need nature; nature needs children too." Just as nature's names are vanishing from the language of children, nature itself is vanishing.

"Forgetting is an easy way to lose things – as each generation becomes more at ease with less nature, we forget what it is that we've lost," says Macfarlane. "Keeping

everyday nature alive in the words and stories of children in particular – who are the ones who will grow up and decide what to save and what to lose – seems to me vital."

And so, two years ago, Macfarlane and artist illustrator Jackie Morris embarked on *The Lost Words*, a 'spell book' they hoped might help close the gap between childhood and nature in Britain.

"At the book's heart was a very simple idea," he explains. "We'd take 20 names for 20 common animals and plants in the British landscape and then, through 'spells' that might be spoken and the beauty of painted images, we would try to summon back those plants and animals into the minds of children."

The result is both enchanting and hopeful. For each name, Morris would first paint its 'absence' – the suckers of an ivy trail without the ivy, the ripple of water reflecting the blue-green of a missing kingfisher, the puddling droplets shaken from an omitted otter. Readers then turn the page to find 'spells' – the first letter of each line spelling out the missing name, and the words and images summoning the character of each creature. The otter is a slippery shape-shifting *underwater thunderbolter*; the marching bramble is snarling cars and stealing through keyholes.

"The otter-spell slipped into my skull while I was walking over the Cairngorms with my father," writes Macfarlane in *The Guardian*. "The willow-spell arrived on the towpath of the River Lea, tramping the unglamorous bank-miles between Broxbourne and Tottenham Hale. The first line of the newt-spell came while I was in the checkout queue at Sainsbury's."

It's a book to thrill the lover of words, rich with the influences of Gerard Manley Hopkins, Dorothy Wordsworth and the metaphorical nature of Old English kennings – the adder has *sine-wave swerves*, ivy scales are like *sky-wire*, the kingfisher is *colour-giver*, *fire-bringer*, *flame-flicker*, *river's quiver*.

The relationship between naming, knowing and nature has long interested Macfarlane. *The Lost Words* grew out of research for his book *Landmarks* (2015), which examined the work of a dozen British and American writers of place, and gathered and organised over 2,000 terms for nature, landscape, creatures and weather from more than 30 languages, dialects and sub-dialects of Britain and Ireland. The book ended with a chapter called 'Childish', about the relationship of childhood and nature.

In the opening pages of *Landmarks*, Macfarlane gives the example of the OJD's 'lost words', which prompted Morris to contact him. "She wanted to see if we could do something hopeful

and powerful to address 'nature deficit' among children in particular," he explains. "Protest can be beautiful", she said to me – and in her art, that is certainly true."

A year after publication, the book has already won two literary prizes, been translated into several languages, and been described by *The Guardian* as "a cultural phenomenon" and by the naturalist and presenter Chris Packham as a "revolution". It is being adapted for film, a choral work, a folk album, classical concerts and outdoor theatre; it's being embroidered in braille and painted on hospital walls. "Certainly, it's been an odd and exciting thing to be part of," says Macfarlane.


Perhaps the most surprising and moving experience for Macfarlane and Morris has been the crowdfunding initiatives that have sprung up after Jane Beaton, a school bus driver from Stirling, raised £25,000 to give the book to all 2,681 schools in Scotland.


In London, The Big Green Bookshop took only four days to raise enough funds to donate a book to the primary schools in the London Borough of Haringey, and the latest campaign by the charity Trees for Cities hopes to raise enough funds to donate a copy to all of the primary schools in Greater London.

"With each campaign, we hear about how the book has been used with the children, and the work and conservation action it has inspired in communities," says Macfarlane. "Access to nature is hugely unevenly distributed across the population, with class, income and ethnicity playing strong determining roles. Many organisations – like the John Muir Trust, which has provided free teacher packs on literacy and outdoor activities to go with the book – specifically aim to help children at risk of social exclusion, or who are otherwise unlikely to reach green places." A proportion of proceeds from each copy of *The Lost Words* is being given to one such organisation, Action for Conservation.

Above all, *The Lost Words* aims to inspire children to love, benefit from and protect the natural world – "to seek, find and speak" it in the pages of the book and in the universe of their landscapes. Macfarlane writes in the book's foreword of an 'old, strong magic', whereby things are never truly lost if they can be conjured back into the mouths and mind's eyes of children.

The Lost Words (2017) is published by Hamish Hamilton.

 **Dr Robert Macfarlane**
Faculty of English

 **Words**
Louise Walsh

The political scientist motivated by a desire to understand the world

“Studying is a kind of release – it lifts you out of yourself”

Alice Musabende has turned her childhood experiences in Rwanda into a quest for intellectual growth. Academic study, she says, enables her to be the person she was meant to be.

What have I done? That’s the question I asked myself when I landed at Gatwick Airport on 10 September 2016. I remember standing in arrivals with my eight-month-old baby, my almost-four-year-old son and a pile of suitcases. I didn’t have a clue about how to get to Cambridge, or how I was going to study and raise a young family alone.

I’m a Gates Scholar. I’m pursuing a PhD in the Department of Politics and International Studies. I feel privileged to be here. This period of my life is a wondrous gift of time and space to become who I am.

I experienced the Rwandan genocide against the Tutsis in 1994. Everyone experiences trauma differently. I was 14 years old and lost my parents, grandparents and all my siblings. My way of coping has been to find solace in an ‘academic’ search to make sense of things such as wars, peace and politics in general. I remain driven by this quest.

My PhD research looks at African international politics. I approach my exploration from the perspective of African political groups. I’m interested in how the African Union interacts with the international system – organisations such as the EU, the UN and NGOs. I want to find out how these interactions affect policies related to peace and security, migration and human rights.

African international politics are complex. It’s important to listen to how Africans, both elites and citizens, navigate



the complex relationships with the various international partners involved in the continent’s political space. Most of the current research comes from an international perspective and often paints Africa’s own politicians and communities as passive recipients.

My work seeks to redress the balance. Africa’s political elites and populaces are far from passive. In the case of the African Union, I’m finding different, and sophisticated, forms of agency, which have the potential to transform the way we think about international cooperation. I prefer to think of my research as underwritten by a need to contribute to the efforts of decolonising – and normalising – the knowledge of Africa’s politics.

Ten years before my arrival in the UK, I’d made another big journey. Aged 26, I flew to Ottawa in Canada from Kigali in Rwanda. I had a scholarship for a Master’s

in journalism at Carleton University. The teaching was fully in English, which was a real challenge. I’d learnt English at school but my undergraduate degree in journalism at the University of Rwanda had been in French.

At lectures and seminars, I didn’t understand much. I knew nothing about Canadian politics and culture. I barely understood how or why the British Queen was the head of state. A wonderful lecturer offered to mentor me. By the time I graduated, I was ready to become a political reporter.

My greatest inspiration is my aunt. She took me in, along with several other children from the extended family who’d been orphaned in the genocide. Her parents and husband had died, and she was grieving and exhausted. But she made sure that I went to school. I wouldn’t be at Cambridge today if it wasn’t for her tenacity.

I went to two Roman Catholic boarding schools. The first one was in the north of the country, away from the city. Two nuns in particular took me under their wings and gave me love. I started doing well and knew that I wanted to attend university as a way of discovering myself.

In my last year of high school, I contracted tuberculosis. It was very hard not to feel defeated, and I was terrified that I wouldn't be able to take my university entrance exams. But somehow I lucked out, I took my medications and got better in time to take my A levels.

There's a lot to learn about Cambridge when you first arrive. The organisational structure is complicated and the environment is academically demanding. The good news is that people help. My PhD supervisor understands my situation as a single parent. Gates Cambridge is, and has continued to be, a fantastically supportive network.

My oldest son goes to the University of Cambridge Primary School. The ethos there is fabulous. He's flourishing and he won't stop talking. He tells people that he goes to the University of Cambridge.

Life has been really tough. But I'm determined that my children's lives won't be defined by my tragedy. If I can do that for them, I can say with real pride that I've succeeded. People ask me how I've managed to get so far. I do think that perhaps one first needs to survive before starting to build a life. I have been very lucky that I was cared for, loved and supported over the years.

Studying is a kind of release – it lifts you out of yourself. By using your mind, and focusing on the wider world, you look beyond your own experiences. My PhD enables me to ask, and seek answers to, profound questions that will, I hope, make a valuable contribution to peace.

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<https://medium.com/this-cambridge-life>



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Interview
 Alex Buxton



DAVID F. LANCY

RAISING CHILDREN

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Detail from an artwork commissioned by the University of Cambridge Primary School (p. 28) to reflect the School's commitment to exploring nature, respecting diversities, releasing the imagination and celebrating the art of the possible. Created by Linda Culverwell (ARTBASH) and Paula Hughes (Lead Arts Facilitator) using childrens' paintings and funded in memory of the late Professor Jean Rudduck from the Faculty of Education.