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THE FIRST INTERNATIONAL YEAR OF PLANT HEALTH

CONSERVATION
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BIOTECHNOLOGY
USING GENE DRIVES FOR CONSERVATION

THE Biologist

THE MAGAZINE OF THE ROYAL SOCIETY OF BIOLOGY / www.rsb.org.uk

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AN ODE TO ELEGANS

Jonathan Hodgkin on a famous model organism

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Cover: Micrograph of *C. elegans* by Sinclair Stammers/Science Photo Library

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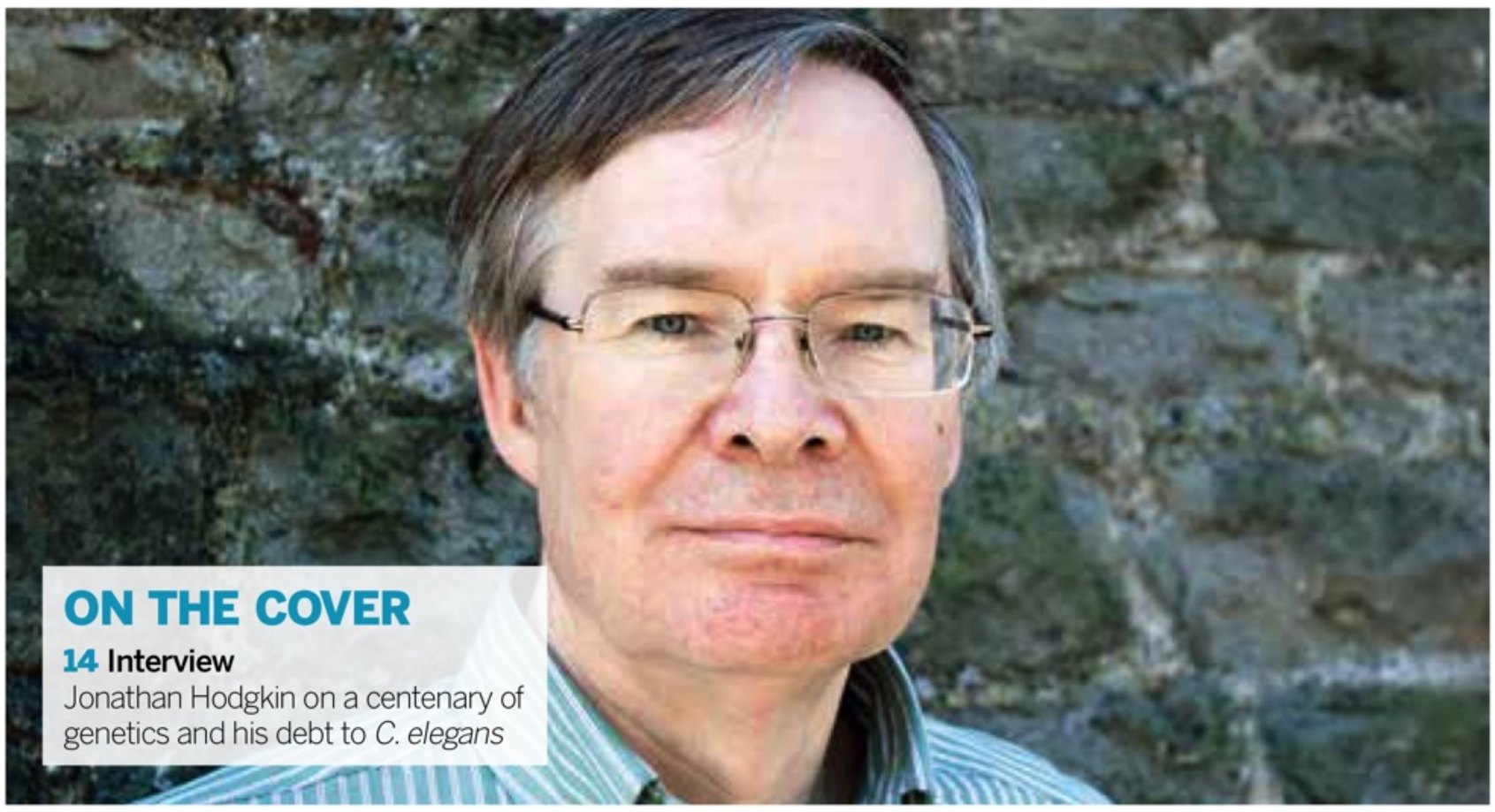
December 2019/January 2020



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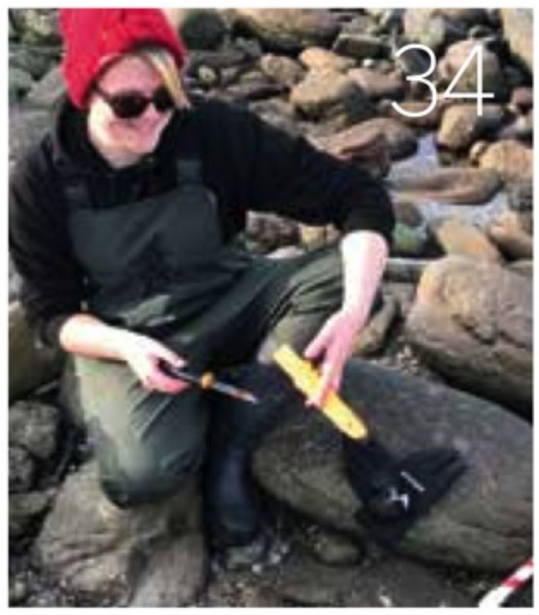

UP FRONT

FEATURES

REGULARS

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WELCOME

What's in this issue

Celebrating 100 years of genetics

As the RSB's year of 10th anniversary celebrations begins, we are coming towards the end of the Genetics Society's centenary celebrations. It has been a busy 12 months for the society, with many activities and events, including genetics-themed installations at the Chelsea Flower Show and the Green Man music festival, a big birthday party and centenary scientific meeting in Edinburgh (from where I'm writing this editorial). There's more on the Genetics Society and its big year on page 37.

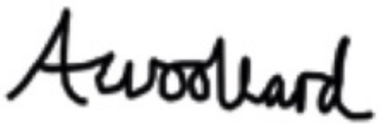
Geneticists often harness the power of the natural world to help answer fundamental biological questions and there is almost no one else in the world who knows more about this than Jonathan Hodgkin, emeritus professor of genetics at the University of Oxford. Hodgkin is our interviewee for this genetics-themed edition, sharing insights from his long, distinguished and joyful career studying the genetics of a huge range of biological questions, from sex determination, through behaviour to pathogenesis. One thing he and I share is a passion for the nematode *Caenorhabditis elegans*, and the remarkable versatility and utility of this humble worm for breaking open new areas of biological investigation. You'll get a great flavour of this by reading his interview on page 14.

Another important genetic feature in this issue is Bruce Whitelaw and Gus McFarlane's insightful article on gene drives. The basic idea with gene drives is to beat Mendelian rules in order to skew inheritance towards one particular version of a gene, rather than following the usual law of 'equal segregation' and allowing natural selection to control gene frequencies over the course of evolution. In nature genes might 'cheat' by finding ways of limiting the transmission of an alternative version, or might get copied more, thus increasing their abundance in the genome. Now, of course, we can use gene editing tools to engineer artificial gene drives, and Whitelaw and McFarlane consider what this approach might have to offer in the areas of public health, conservation and agriculture. It's fascinating stuff, and I couldn't agree more with their conclusion that both Mendel and Darwin would be blown away by this.

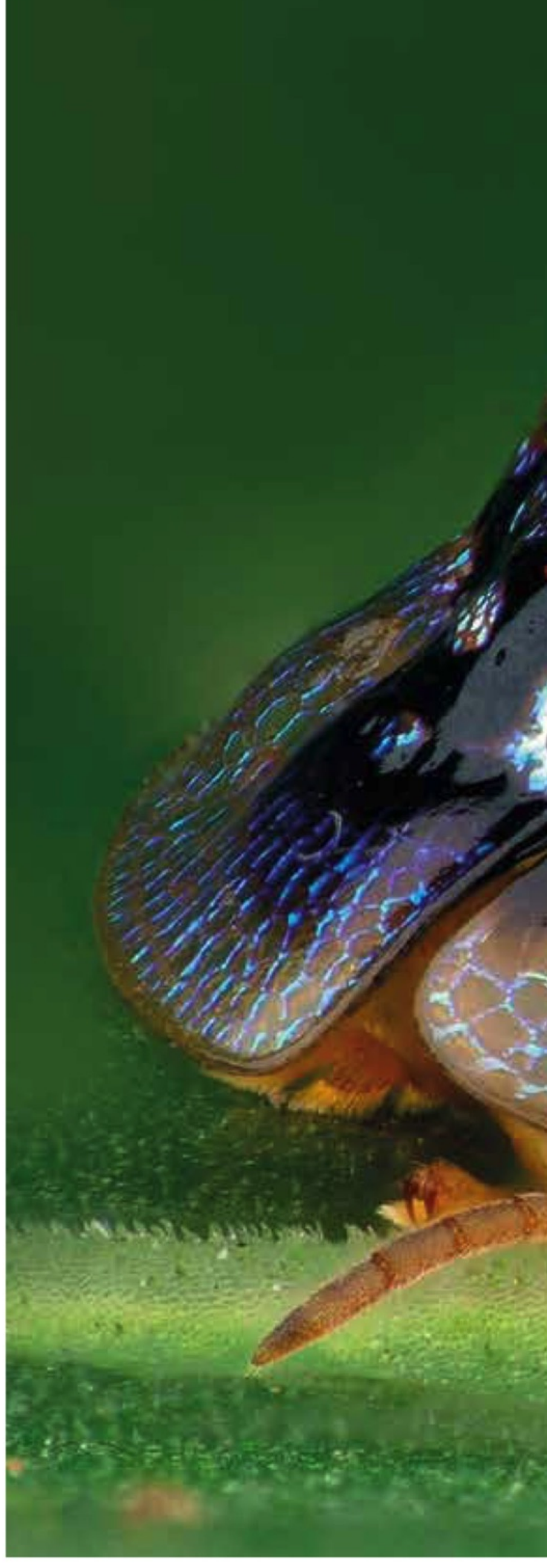
As genetics is all about observing, manipulating and learning from the natural world, it seems fitting to celebrate this too. So I hope you enjoy the amazing winning entries from the RSB's photography and drawing competitions, Kevin Nicholas on what we humans can learn from the amazing power of marsupial milk and Janelle Kaz's fascinating conservation stories, all from the back of her motorbike!

A joyous end to this year and an upbeat look forward to the next? Fingers crossed. Happy festive season!

Geneticists often harness the power of the natural world to answer questions



Alison Woollard FRSB
Chair, Editorial Board of The Biologist



BioPic

UNKNOWN TORTOISE BEETLE (CASSIDINAE), ECUADOR

Andreas Kay

This striking beetle from the Cassidinae subfamily of leaf beetles (known as tortoise or leaf-mining beetles) was taken by Ecuadorian biologist and photographer Andreas Kay, who sadly died in October. Kay discovered many new species of plants, including the orchids *Lepanthopsis kayii* and *Lepanthes kayii*, and he was a co-founder of the Dracula Reserve in northern Ecuador. He leaves behind almost 30,000 images, which can be found on his 'Ecuador Megadiverso' collection on Flickr.

www.flickr.com/photos/andreaskay/sets

From left: Julia Higgins, Athene Donald, Carol Robinson and Julia Goodfellow

EVENTS

Science sector presidents discuss STEM careers at conference

Three presidents from the Royal Society of Biology, the Royal Society of Chemistry and the Institute of Physics sat down for a interview with Professor Dame Athene Donald FRSB as part of the Daphne Jackson Trust 2019 Conference.

Professor Donald, a patron of the Daphne Jackson Trust, talked on stage with RSB president Professor Dame Julia Goodfellow, former president of the Institute of Physics Professor Dame Julia Higgins and president of the Royal Society of Chemistry Professor Dame Carol Robinson.

The four women discussed a number of topics, including career challenges, the benefits of joining a professional society and future aspirations for the scientific community.

In attendance were current and former Fellows, trustees, and representatives from hosts and sponsors, as well as people who work in the science policy, research and higher education sectors.

Since the first Fellowship in 1986, the Daphne Jackson Trust has facilitated professional development and provides support for those returning to STEM careers after a career break.

The three societies also worked together this year to deliver the first joint conference for science apprentices, supporting skills development and the further stages of their career.

Read more about the interview at bit.ly/2QhI1qB

EVENTS

A bumper year for bioscience outreach

Visitors at the Big Bang Fair

More than 12,000 people engaged with the RSB's hands-on science outreach activities in 2019, not including events organised by the Society's regional branches.

With invaluable assistance from hundreds of volunteers, the RSB's outreach team delivered activities at 14 events this year, from the enormous Big Bang Fair at Birmingham's NEC Arena to small local festivals such as Conwy Feast and Ipswich Maritime Festival.

Meanwhile, more than 65,000 students from 1,750 schools in over 40 countries took part in this year's biology competitions: the Biology Olympiad, the Biology Challenge and the Intermediate Biology Olympiad.

A further 200 people attended the Society's Bioscience Careers Day in October and for the first time representatives from the RSB marched as part of the Pride in London parade.

EVENTS

HUBS 2020 conference to focus on diversity

The Heads of University Biosciences (HUBS) Annual Meeting 2020 will be held from 20th to 21st April at the Francis Crick Institute, London.

The two-day conference will include sessions on research, higher education policy, and teaching and learning in the biosciences. It will focus on the theme of equality and diversity, and will include networking opportunities, a wine reception and conference dinner.

See hubs2019.rsb.org.uk for details.

COMPETITIONS

School biology contests 2020 open for entries

Registration is now open for both the British Biology Olympiad 2020, which will be held from 31st January to 7th February, and the Biology Challenge 2020, which will run from 10th to 31st March.

The British Biology Olympiad challenges students aged 16 and above to demonstrate their knowledge of biology, while the Biology Challenge tests students aged 13 to 15. In both competitions high-scoring students will receive certificates and be invited to an awards ceremony in London.

Visit www.rsb.org.uk/competitions or email competitions@rsb.org.uk for details.

FUNDING

RSB invites applications for overseas travel grants

Student and early-career members of the Royal Society of Biology can now apply for a travel grant of £500 to support future overseas travel in connection with biological study, teaching or research.

Further details on eligibility and how to apply can be found at www.rsb.org.uk/travelgrants. The deadline for applications is 1st March 2020.

AWARDS

The Biologist scoops publishing industry prize

The Biologist has won 'best specialist magazine' at the 2019 Scottish Magazine Awards (SMAs).

The Society's magazine has received several accolades at the SMAs since moving to Glasgow-based publisher Think in 2012, including best design and editor of the year.

MEDIA

Society teams up with ITN in biology news programme

The RSB and ITN have co-produced a news and current affairs-style programme, *Biology Impacting Lives*, on the advancement of life science and its impact.

Presented by newsreader Natasha Kaplinsky OBE, the programme highlights ground-breaking research taking place in universities, industry and in the field.

The video can be watched and shared at bit.ly/RSB_ITN_Film

In case you missed it...

The editor's pick of biology stories being shared online


Fly killed by *Entomophthora muscae*

Jerzy Gubernator/Science Photo Library

FUNGUS FIRES ARTILLERY FROM ATOP ZOMBIE FLIES

A team of researchers from the University of Copenhagen have reported an extraordinary new observation in a parasitic fungus and its host.

After fatally infecting house flies, *Entomophthora muscae* determines when and where the fly dies so that it is in the best position to release fungal spores. The fungus then grows out of the back of the fly, developing "microscopic cannons" to launch spores onto unsuspecting flies that get too close to the dying insect.

The researchers, who originally set out to find natural inspiration for fly traps, say the spore-launching system could inform new ways to defend against disease-spreading flies.

THE NEW YORK TIMES

bit.ly/fungalartillery

'PRIME EDITING' BOOSTS GENE-EDITING ACCURACY

A new CRISPR-based technique known as 'prime editing' could vastly improve the way researchers replace and correct genes when using gene-editing technology.

The technique directly writes new genetic information into a specified DNA site using an engineered reverse transcriptase, guided by the Cas9 protein and guide RNA, that both specifies the target site and encodes the desired edit.

The team at the Broad Institute say it is "very versatile and precise", and could be used to correct large numbers of disease-causing mutations at once, but stress the research is only starting.

NATURE

bit.ly/NewPrimeEditing

BREAKTHROUGH PRIZE 2020 FOR WORK ON PAIN, ADIPOSE TISSUE AND 'MOLECULAR CHAPERONES'

Five bioscientists have been named in the life science category of the 2020 Breakthrough Prize, receiving a share of the $21m prize fund.

Jeffrey M Friedman was honoured for the discovery of a new adipose tissue-based endocrine system; Franz-Ulrich Hartl and Arthur L Horwich for revealing functions of molecular chaperones in mediating protein folding; David Julius for discovering molecules, cells and mechanisms underlying pain sensation; and Virginia Man-Yee Lee for finding the TDP43 protein aggregates that play a key role in dementia and Parkinson's disease.

The prize, funded by sponsors including Google's Sergey Brin and Facebook's Mark Zuckerberg, bills itself as the 'Oscars of Science' and recognises achievements in the life sciences, fundamental physics and mathematics.

@BRKTHROUGHPRIZE

bit.ly/breakthroughprize

BIOSCIENCE COLLECTIVE SETS OUT ACTIONS TO TACKLE CLIMATE CRISIS

A group of 11,000 scientists have laid out a broad range of indicators of climate change and urgent actions required to prevent "untold suffering".

The statement in the journal *BioScience* came from a collaboration of dozens of scientists and was endorsed by a further 11,000 researchers in 153 nations. The group says that the urgent changes needed include stabilising population growth, restoring forests and mangroves, leaving fossil fuels in the ground and slashing the consumption of meat.

The warning also sets out a full range of "vital sign" indicators of climate breakdown, rather than only carbon emissions and surface temperatures.

THE GUARDIAN

bit.ly/11000scientists

OPINION

Christopher Wills AMRSB is a graduate in forensic science from Anglia Ruskin University, a fledgling scientist dealing with epilepsy for the past eight years

Out of sight, out of mind?

Christopher Wills on 'hidden' disabilities and the life sciences

What's it like having epilepsy? People are curious about seizures – what to do if I should have one, how common they are. My usual answer is that mine are mild, and that I have a medical ID in my wallet. However, I don't tend to tell them about nearly falling asleep at 4pm on a hot day because of fatigue. I never tell them about my lost childhood memories, or how words can just ...

Sorry what was I saying? Ah yes – invisible disabilities. As the name suggests they are disabilities that are not necessarily visible or obvious. There are 11 million people with disabilities in the UK and, according to one BBC article[1], 74% of people with disabilities don't use a wheelchair or anything else that shows they are living with a condition. According to the disability charity Scope, two in five people with disabilities actively hide their condition.

A person with a health condition with obvious or well-known symptoms may also have multiple challenges related to that condition that are not immediately obvious. For example, epilepsy can cause seizures, but can also lead to apathy, fatigue, poor memory and language issues – which in turn can lead to problems with self-confidence, anxiety and depression.

The challenges and the needs of the people suffering with invisible disabilities vary massively, as does the list of conditions that qualify as an invisible disability. Autism, chronic fatigue syndrome (ME), chronic pain, cystic fibrosis, depression, ADHD, bipolar disorder, schizophrenia, diabetes, epilepsy, fibromyalgia, HIV/AIDs, insomnia and rheumatoid arthritis are just a few.

Employment of people with disabilities in the UK has always been worse than for people without – according to the latest UK Government figures, 46% of working-age disabled people are in employment compared to 76% of working-age non-disabled people. But the figures are worse in STEM. According to one study[2], "STEM fields have 75% fewer people with disabilities than the general population". One article in *Science*[3] by Jesse Shanahan states that only "9% to 10% of undergraduates are disabled," with just 1% of PhD holders having a disability.

Invisible disabilities may prevent someone from applying for a job, may prevent them from getting to an interview, or may make someone seem less equipped for the role. In science, researchers are also expected to be active in the countless events and conferences taking place across the UK and the world throughout the year, something I have found very difficult. Some people with invisible disabilities require regimentation and order to function well; I need a regular work and life schedule to reduce the risk of seizures and SUDEP (sudden unexpected death in epilepsy). Yet there are also those who require flexibility in their work to adjust for their condition. Then there are those of us who need regimentation day to day but flexibility when conditions flare up.

Those of us with hidden disabilities understand how hard it is to accommodate these conditions – after all, we have to live with them. But greater awareness can help both employers and employees.

As Sheryl Burgstahler states in an article for *Information Technology and Disabilities*[4], one of the three core barriers for people with disabilities, invisible or otherwise, is "acceptance by educators, employers and co-workers". If employers and HR managers were more knowledgeable on hidden disabilities it could make

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1) The hidden challenges of invisible disabilities. *BBC Worklife* [online] [Accessed 17 July 2019].

2) Atchison, C. L. & Libarkin, J. C. Professionally held perceptions about the accessibility of the geosciences. *Geosphere* **12** (4), 1154-1165 (2016).

3) Shanahan, J. Disability is not a disqualification. *Science* **351** (6271) p418.

4) Burgstahler, S. Increasing the representation of people with disabilities in science, engineering and mathematics. *Information Technology and Disabilities* **1** (4) (1994).

5) The safety of laboratory workers with disabilities. RSC, May 2013.

workplaces more accepting of those people with hidden disabilities.

There are several programmes or organisations that can help companies and other bodies. Disability Confident is a government-run scheme which offers guidance and resources on employing people with disabilities. The Employers Network for Equality and Inclusion is an employer network which offers bespoke training and consultancy to promote equality and diversity in the workplace. And Scope has started the #workwithme scheme, which is "a call to action for businesses to come together to create more inclusive workplaces for disabled people". There is also STEM-specific guidance available, such as the Royal Society of Chemistry's guide to improving lab access for people with disabilities[5].

Little things can make huge differences to helping a person living with a disability feel more open to discussing their condition and what accommodations they require. Given that many in the life sciences research, diagnose and treat these conditions, it would be fitting if this sector could also lead the way in accepting people with hidden symptoms in the workplace.

Biology Week 2019

UK votes the otter as its top freshwater species

The UK's elusive but charismatic common otter (*Lutra lutra*) was named the UK's favourite freshwater species at the end of another successful Biology Week.

The otter received almost 5,000 public votes before and during Biology Week 2019, narrowly beating the water vole and the Atlantic salmon.

Alongside this year's poll, the Royal Society of Biology published a number of free downloadable education resources on freshwater habitats and freshwater species, including dragonflies, newts and crayfish.

Environmental crises dominate Biology Week

Biologists and non-biologists of all ages packed into the historic Faraday Theatre at the Royal Institution during Biology Week to hear a panel of experts tackle the question: 'Marine plastics – is it too late to save our oceans?'

The audience first heard from chair and environmental journalist Gaia Vince that 300 million tonnes of plastic is produced every year; that just 20% is recycled or incinerated; and that much of the rest has spread through our ecosystems – some of it entering our own bodies as microplastics.

An expert panel representing areas including toxicology, ecology, materials science and marine advocacy debated the harm caused by plastic in the ocean, the reasons for the scale of the problem and potential solutions. Marine campaigner and diver David Jones received applause for his view that plastics manufacturers should be held responsible for the problems their products are causing.

Dr David Ware FRSB and RSB president Professor Dame Julia Goodfellow

He said: "There is a reason you don't see plastic bottles on the floor in Germany and that's because they are worth 25 cents each. That system is paid for by the people who make the plastic and they've been doing that since 1992. It's time we caught up."

Earlier in the week the Society organised a Policy Lates event to discuss declining insect numbers. A panel of experts discussed how different datasets on insect populations can tell different stories. They concluded that, although it is clear that insects are under threat, far more data is needed to understand exactly what is going on and why.

The RSB also celebrated competition winners (see page 10) and high-achieving members during Biology Week. This year's President's Medal was presented to Dr David Ware FRSB for outstanding service and commitment to the Society. Dr Ware has been secretary of the Kent, Surrey and Sussex branch for more than 10 years.

Watch the marine plastics debate at bit.ly/34Ya8zc and listen to audio from the insect declines debate at bit.ly/32KiHMG

The common or Eurasian otter *(Lutra lutra)*

Professor Dave Pape

ENVIRONMENT

Tens of thousands invited to climate change assembly

In November 30,000 people from across the UK were invited to join a citizen's assembly on climate change.

Of those who reply, 110 will be selected to take part in the four-weekend Climate Assembly UK workshops. Participants will discuss and recommend how the UK can reach its target of net zero emissions by 2050.

The assembly was launched before the dissolution of parliament to ensure its report is available to the new parliament.

HEALTH

Resistance rising despite fall in antibiotics use

The number of drug-resistant infections in the UK rose by 9% between 2017 and 2018 to nearly 61,000, despite a 17% drop in the number of prescriptions for antibiotics in England over the past five years.

Public Health England's annual report on antimicrobial resistance for 2018–2019 found that the most potentially serious infections (antibiotic-resistant bloodstream infections) rose by a third between 2014 and 2018.

Reducing the use of antibiotics is a key strategy in limiting the emergence and spread of antimicrobial-resistant bacteria.

Public Health England's Dr Susan Hopkins said it was "worrying" that more infections were becoming resistant to life-saving antibiotics, but said it was good news that prescriptions for antibiotics had come down from their peak in 2014.

FUNDING

New report focuses on international collaboration

Professor Sir Adrian Smith has published his report advising on the future of UK funding for international collaboration, innovation and research.

Professor Smith, director and chief executive of The Alan Turing Institute, was commissioned by the Government to advise on how funding streams for international collaboration could best be designed to positively impact science, research and innovation in the UK.

His advice can be found at bit.ly/BEISadvice

BREXIT WATCH

FUTURE FUNDING

The Government has released advice for individuals who receive funding from an EU programme or have applied to one, amid continuing Brexit uncertainty.

There are guidance documents for various funds and programmes such as Horizon 2020, LIFE, Euratom and BEST.

The Government has guaranteed that organisations will continue to receive funding for certain EU programmes if the UK leaves the union without a deal or agreement on continuation of funding for UK research.

Organisations that may be eligible for the UK Government's guarantee are urged to register.

See bit.ly/Brexit_science_advice

HORIZON ASSOCIATE COUNTRIES FEAR LOSING 2021 FINANCE

The UK could miss out on the beginning of the €100bn (£86bn) Horizon 2021 programme due to delays in negotiating the EU's long-term budget, new rules for associating nations, and the terms of the UK's withdrawal bill.

The UK and Switzerland, along with new associated nations such as Australia and Canada, are all likely to miss out on collaborations awarded at the start of the next framework programme due to the stalled negotiations.

However, the UK's science minister, Chris Skidmore, told *Times Higher Education* that it was still possible the UK could join the programme from the start. He said the rules for the 2020 programme were also finalised late and still allowed associated nations to join.

GOVERNMENT

Review says new models are needed to shore up government science

The Government Office for Science has published a series of recommendations on improving the use of science and engineering by government.

The Science Capability Review found that the use of and expenditure on science is variable across government, with reduced budgets in many departments.

It recommends that to improve the impact of government science, it is necessary to work with the wider scientific community in academia.

According to the review, the UK's public laboratories are "an extraordinarily valuable asset", but need nurturing. It also recommends that new models for working with private sector innovative companies will be required to meet the science needs of government.

See bit.ly/GOS_review

CLIMATE CHANGE

Government launches £50m initiative to encourage tree planting

The Government is rolling out a £50m Woodland Carbon Guarantee scheme to encourage farmers and landowners to plant more trees and help to tackle climate change.

Landowners and land managers will be encouraged to invest in carbon sequestration, with payments made as their woodland grows.

Land managers must register their projects with the Woodland Carbon Code – the standard for UK woodland creation projects – and will be offered the option to sell Woodland Carbon Units to the Government over 35 years.

POLICY

Green legislation progresses unopposed

The Government's Environment Bill has passed its second reading by MPs unopposed and will now progress to Committee stage.

The legislation aims to create legally binding environmental improvement targets. A new independent Office for Environmental Protection will be established to scrutinise environmental policy and law, investigate complaints and undertake enforcement action against public authorities to uphold environmental standards.

The office will also hold the Government to account on its commitment to reach net zero emissions by 2050.

The bill introduces policies and targets from the Government's 25-year plan for the environment, which includes measures to reduce single-use plastics and restore habitats.

Dr Celia Knight FRSB MBE Plant science education and employability consultant
Professor Nicola Spence FRSB DEFRA's chief plant health officer and president of the British Society for Plant Pathology

A new year takes root

Celia Knight and Nicola Spence look ahead to 2020: the International Year of Plant Health

Plant health is important to all of us: it affects our food supply, our environment and our economy.

Maintaining plant health in a changing climate is a global problem and will be acknowledged by 2020 being designated the International Year of Plant Health (IYPH).

DEFRA's plant health risk register lists over 1,000 pests that threaten our crops, gardens and countryside. To take just one example, *Xylella fastidiosa* is a bacterial wilt disease causing significant damage to olive trees in southern Europe. Many UK plants would be at risk if plants infected with *X. fastidiosa* were imported. Another entry to note is the emerald ash borer, which is currently requiring surveillance to prevent entry from eastern Europe and protect UK ash trees already affected by ash dieback disease.

The proposal for 2020 to become the IYPH was initiated by Finland and agreed by the United Nations in December 2018. Since then countries across the world have been working on events to promote plant health to a global audience. The Food and Agriculture Organisation of the United Nations and the International Plant Protection Convention have produced a 'getting started guide' and visual identity guidelines[1]. A team within DEFRA are co-ordinating UK events alongside partners with interests in plant health.

Activities will run throughout the year, but will be focused around a new national Plant Health Week. It will encompass World Earth Day and take place from 20th to 27th April 2020, and will become an annual event thereafter. Plant Health Week will provide a focus for activities aimed at industry, academics and the general public to improve awareness of the importance of keeping plants healthy. The Plant Health Portal[2] will provide further information on plans for IYPH in the UK.

The UK Plant Sciences Federation (UKPSF) is organising a workshop (20th to 22nd October at Fera Science in York) for plant professionals from sectors including agriculture, horticulture, forestry, biotechnology and any area in which plant health is important. Structured discussions guided by professionals will help those early in their careers extend their networks and contribute to addressing the challenges. Look out for further details and information on how to apply through the UKPSF newsletter.

Plant health is a great way to engage the wider public in outreach and STEM education activities

We encourage all biologists to think about creating opportunities to engage more people with IYPH 2020's message. You don't have to be a plant pathologist to share with your colleagues, friends and family the importance of plant health, and the UKPSF will be pleased to direct enquiries to the relevant Member Organisations[3].

The Society itself also runs plant health undergraduate studentships[4] and the Plant Health Professional Register[5].

The professional register is now aligned to the horticultural sector's Plant Health Management Standard. This is available on the Plant Healthy website[6], which promotes the standard to people who work with and grow plants.

Plant health is a great way to engage the wider public in outreach and STEM education activities, and to show that plants offer wide and varied career opportunities. If any members or local branches of the RSB would be interested in staging an IYPH 2020 event next year with their local plant health professionals, we can help make the connections.

As we approach 2020, let's all use the international year designation to make a real difference.

REFERENCES
1) ippc.int/en/iyph/
2) planthealthportal.defra.gov.uk
3) plantsci.org.uk/communities/member-organisations
4) bit.ly/PHstudentships
5) bit.ly/PHPregister
6) planthealthy.org.uk

Capturing movement

The RSB's hugely popular photography and drawing competitions attracted more than 900 entries from across the world and the winners received their prizes during Biology Week

The theme of this year's photography competition was 'capturing movement' and entrants were invited to photograph motion, rhythm and activity in living organisms. The beautiful shortlisted images were published by *The Times*, the BBC and *The Guardian*, and first place was awarded to Nick Edwards for his photograph of a 'demob happy' red soldier beetle.

PHOTOGRAPHER OF THE YEAR

WINNER (right)
'Demob Happy' **by Nick Edwards**
"I have never seen a happier-looking insect. Being a soldier, it must have been going home to be that elated." This red soldier beetle (*Rhagonycha fulva*) was captured mid-flight towards Edwards' camera in Thorness Bay near Cowes, Isle of Wight, UK.

RUNNER-UP (below right)
'Male Polar Bear Shaking Off Snow' **by Ian Stone**
A polar bear shakes snow off itself on the frozen shore of Hudson Bay, near Churchill, Canada. "Moments before, the polar bear had been 'hunkering down', sheltering from a snowstorm, and then its first instinctive movement was to stand up and get rid of the snow by shaking its whole body."

RUNNER-UP (main image)
'Flying Over Sunshine' **by Kristhian Castro**
A black-throated mango hummingbird (*Anthracothorax nigricollis*) taken in the Valle del Cauca, Colombia. "This family of birds (Trochilidae) can flap its wings up to 75 times per second and at this shutter speed (1/200sec) its wings became almost invisible, so I used the sunlight to capture its movement."

HIGHLY COMMENDED (bottom)
'Territorial Fight' **by Sudhir Gaikwad**
"Mudskippers (Oxudercidae family) are highly territorial and will chase away any intruders that cross into their territory," wrote Gaikwad, who took the image in the Sunderbans National Park, India.

For details of all the shortlisted entries, visit bit.ly/RSBphotocomp2019

The Society would like to thank Eppendorf for its continued support of this competition and the judges, Tim Harris, Tom Hartman, Alex Hyde and Linda Pitkin CBiol MRSB

YOUNG PHOTOGRAPHER OF THE YEAR

WINNER (bottom)
***'Fighting'* by Carlos Perez Naval (14)**
"Two male white-headed ducks (*Oxyura leucocephala*) fighting, in springtime, captured in Navaseca, Ciudad Real, Spain."

RUNNER-UP (top)
***'The Stampede'* by Lillian Quinn (16)**
"A stampede of zebras crossing the Maasai Mara National Reserve in Kenya as they quickly and bravely dodge crocodiles and other dangers during their annual migration."

RUNNER-UP (left)
***'Playtime'* by Amogh Gaikwad (16)**
"After hunting in the Tadoba Tiger Reserve, India, this 15-month-old tiger cub decided to play with its recently captured prey."

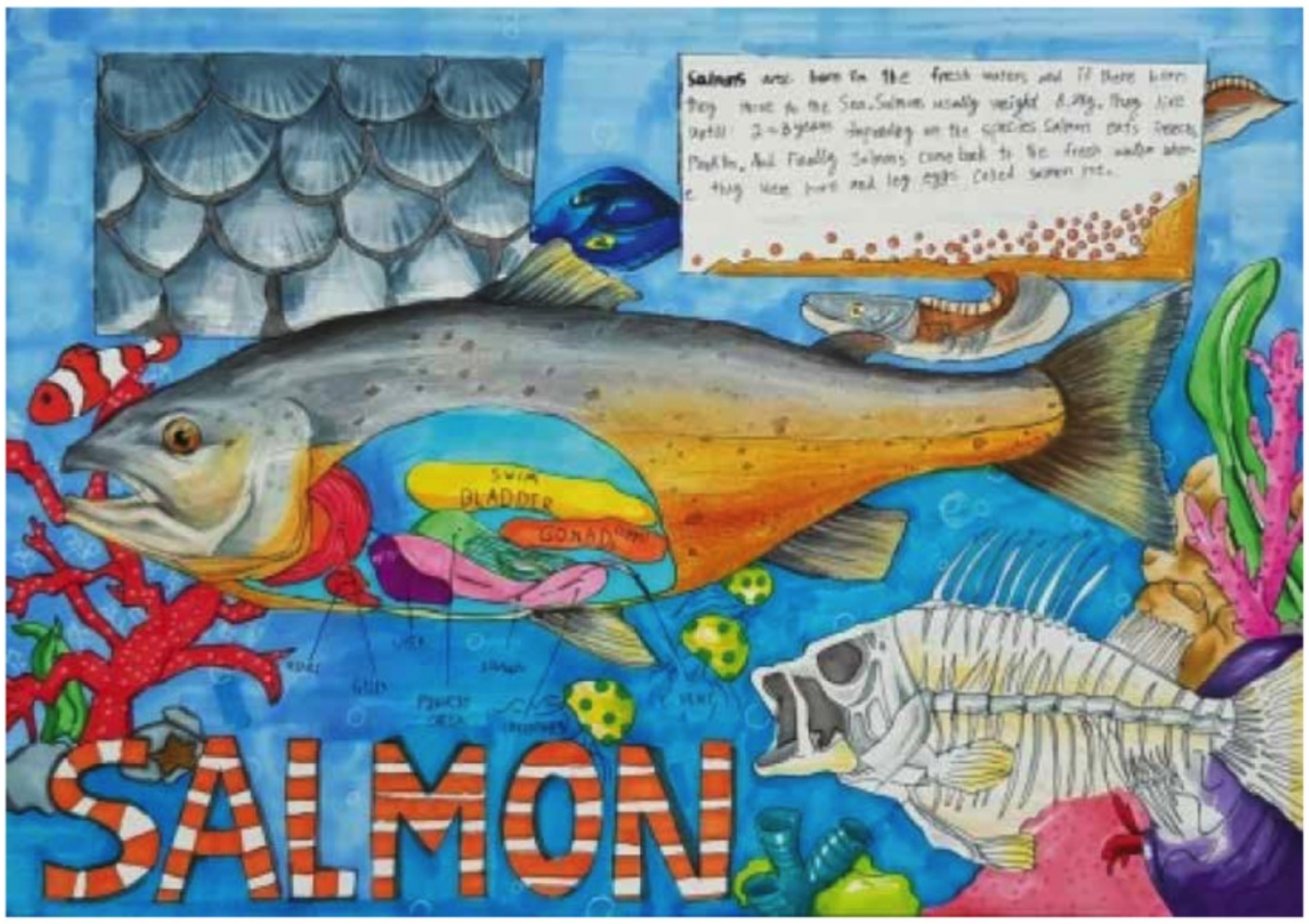
HIGHLY COMMENDED (far left)
***'Hectic Nature'* by Will Lawson (16)**
"This rare swallowtail butterfly (*Papilio machaon*) pictured at Hickling Broad, Norfolk, momentarily sat feeding after some frenzied fluttering around.
Even when the majestic individual was resting, other creatures were still rushing around, such as the wasp to the right of the image."

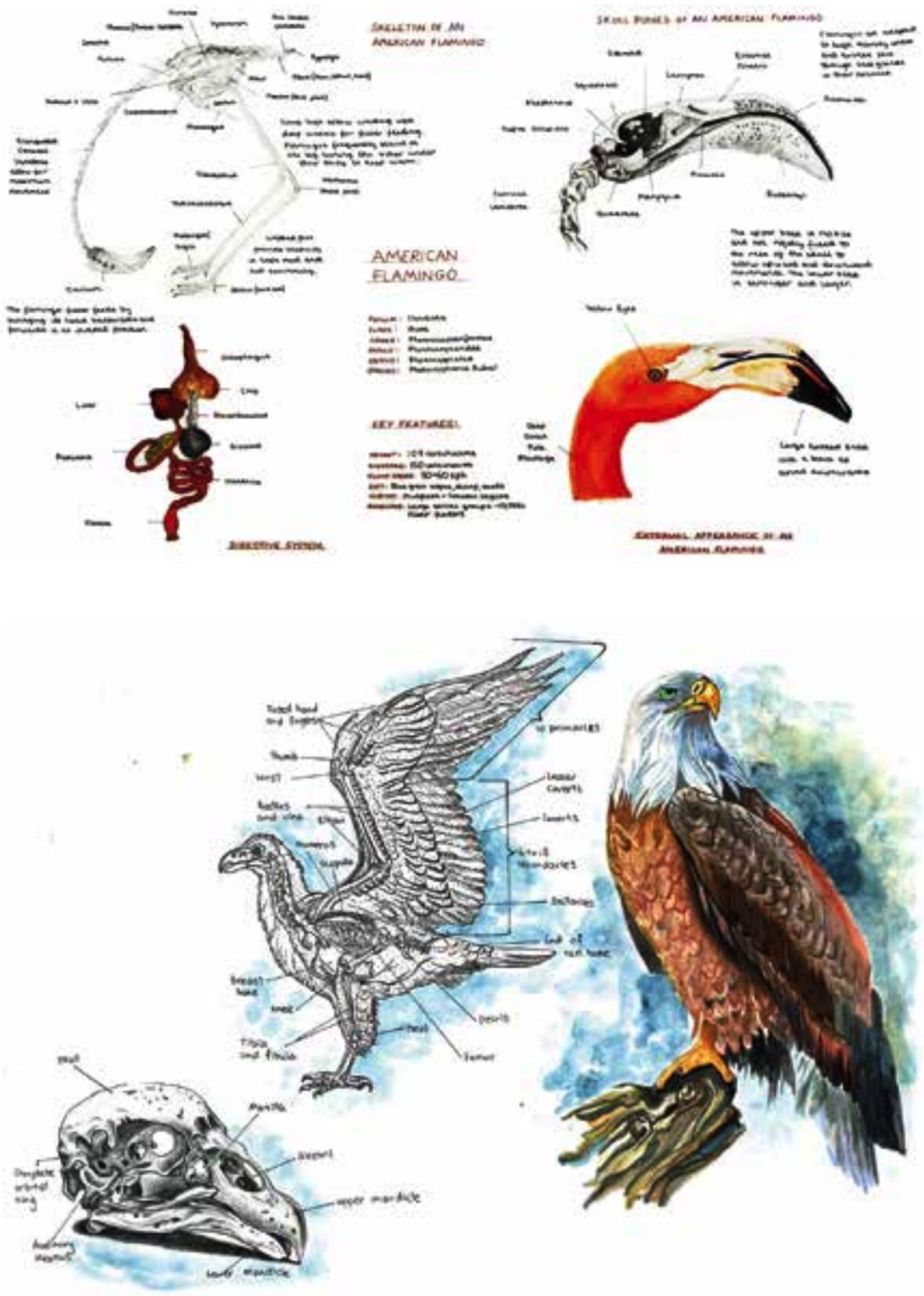
The Nancy Rothwell Illustration Awards celebrate specimen drawing in schools, highlighting the benefits of combining art and science. Prizes include an experience day at the Royal Veterinary College, a set of drawing pencils and cash for the entrant and their school.

More than 500 pieces were submitted by young artists from across the globe.

"All of the entries were simply stunning," said illustrator and competition judge Timothy Pond. "This award brings forward the best in children in both artistic and scientific rigour, and I have been impressed by the deep biological understanding that even young individuals present."

For more information on all the shortlisted entries, please visit bit.ly/RSBdrawingcomp2019





NANCY ROTHWELL ILLUSTRATION AWARDS

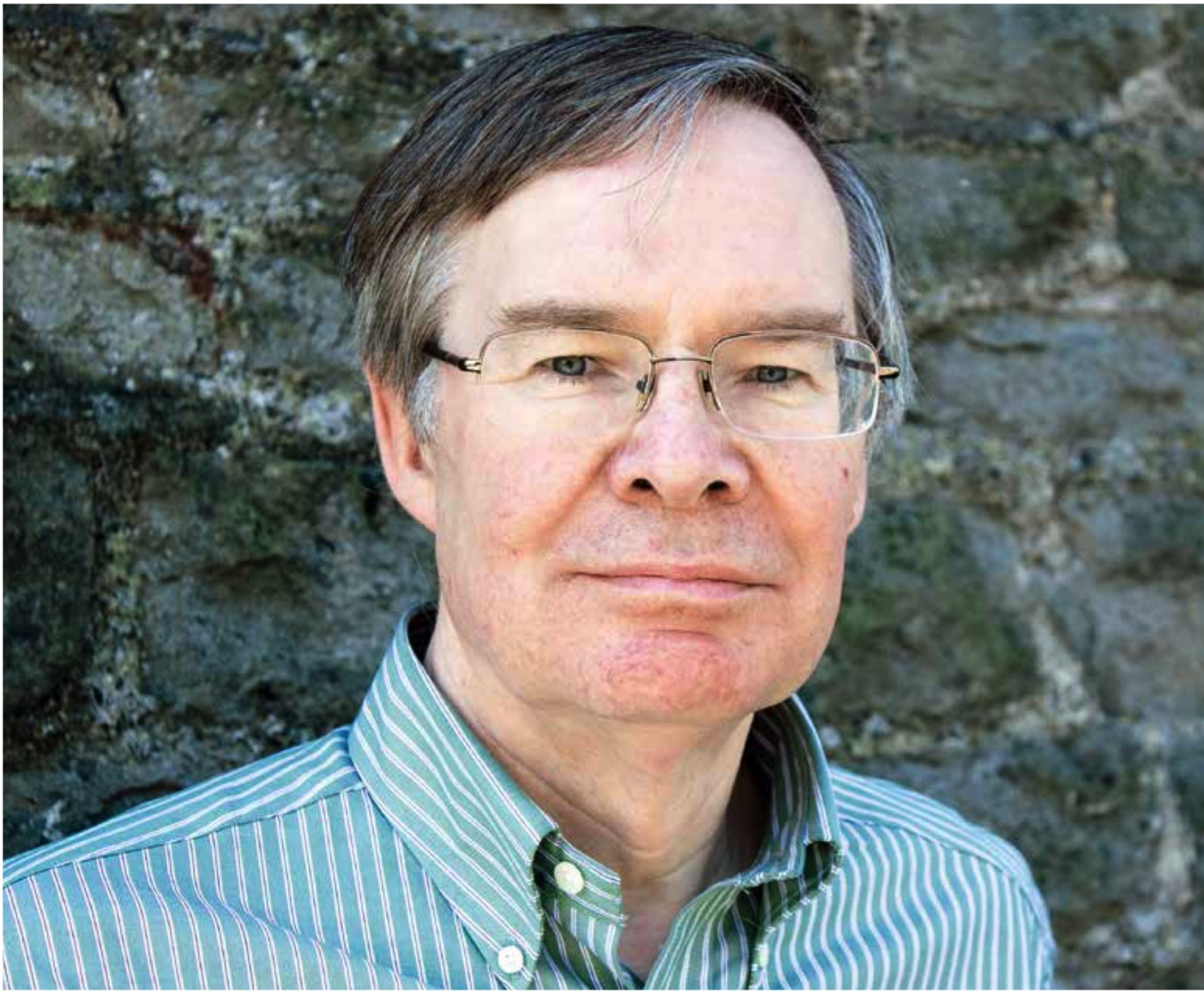
WINNER (above)
7–11 age group
Jiyoo Erin Lee, Seoul Foreign School, South Korea (coloured pencil and pen)
The judges commented: "This sensitive portrait of a salmon by Jiyoo shows an extraordinary talent. The colours are carefully mixed with markers and applied with a high level of skill and craft. The illustration glows with warmth and the cutaway leads into an understanding of what is going on within the biology of the organism."

WINNER (left, middle)
12–14 age group
Catherine James, Lady Eleanor Holles School, Hampton (coloured pencil)
According to the judges: "Catherine has shown a tremendous level of understanding in this detailed depiction, giving us an insight into the flamingo's skeletal structure and underlying biology. The flamingo is an original choice and the head is a beautifully rendered illustration with sublime colour."

WINNER (left, bottom)
15–18 age group
Serena Liu, UWC South East Asia, Singapore (coloured watercolour pencil, pen)
The judges said: "An excellent depiction of this iconic species. Serena gives us a visualisation of the appearance of the bald eagle and an anatomical breakdown of the subject from its skull and skeleton to its plumage. This is an extremely skilled piece packed full of information both biological and artistic."

The Society wishes to thank the Royal Veterinary College for its continued support of this award and judges Andrew Crook MBE FRSB, Lucy Eckersley AMRSB, Tom Ireland MRSB, Dr Grace Sim, Timothy Pond and Professor Susan Standring FRSB

‘There’s something new every day, after all these years’



To celebrate 100 years since the formation of the Genetics Society, Alison Woollard talks to geneticist **Jonathan Hodgkin** about a century of remarkable progress, and what they both owe to mutant worms

Jonathan Hodgkin FRS is emeritus professor of genetics at the University of Oxford and a former president of the Genetics Society. In the 1970s he was a student of Sydney Brenner, the first researcher to suggest the nematode worm *Caenorhabditis elegans* could be used to study fundamental biological

processes. *C. elegans* went on to become a key model organism in genetics, development and neuroscience and has been central to Hodgkin's career ever since. It was the first multicellular organism to have its whole genome sequenced and remains the only organism to have had its entire 'connectome' (neural wiring) mapped.

Hodgkin's early work at the Laboratory of Molecular Biology in Cambridge helped elucidate the complex genetic pathways that determine whether individual worms become male or hermaphrodite (see 'Sex determination in *C. elegans*', p17), but in his long career he has explored many other developmental pathways and the genetic basis of behaviour.

More recently Hodgkin has focused on the nematode's innate immunity to attack by various bacteria, which has helped identify antibacterial factors that could be candidates for new antibiotics.

Hodgkin was elected a Fellow of the Royal Society (FRS) in 1990 and received the Genetics Society Medal in 2011. He is the son of Nobel Prize-winning biologist Alan Lloyd Hodgkin.

Jonathan, it's really great to be talking to you as we celebrate a century of genetics. What got you into it?

Largely brilliant teaching at university. I remember reading a genetics textbook in sixth form and not understanding a word of it. A couple of years later it all made sense thanks to, among others, a particularly good fungal geneticist called Brian Cox. No, not that one.

Then, as I became interested in developmental biology it was obvious that genetics was going to be the most powerful tool to work out what exactly was going on with development.

Tell us how you got started looking at *C. elegans*.

It was because of Sydney Brenner, who had realised that you could use this organism in enormously powerful ways. I heard a lecture from him in my final year of university and was totally inspired by that. When I graduated I persuaded him to take me on as his graduate student. That was a very, very good decision.

I mean, he was a great believer in choosing the right organism for what he worked with. He went from phages and bacteria to *C. elegans*, and then got involved with various genome projects.

He was interested in fish too, wasn't he?

He liked fish, yes, among other things. His first paper was on the chromosomes of elephant shrews in South Africa. Later on he rather neatly did the complete genome of a weird creature called the elephant shark.

Did anyone think you were a bit mad to follow Sydney's call to study *C. elegans*?

Some people were very sceptical of the whole *C. elegans* project. Other people had faith in Sydney – they could see that this was basically a genius who had settled on a terrific system and it was going to go places. He also inspired a lot of other people to join him, so in the end it wasn't just about Sydney, it was all the other people that came in.

Why worms?

All laboratory strains of *C. elegans* are thought to be derived from one individual isolated from soil in Bristol in the 1950s. These tiny worms, around 1mm in length, replicate roughly every three days and are transparent, making them ideal for studying genetic and developmental changes. They are easy to grow, with many hundreds fitting on a single agar plate, and remain viable after being frozen and thawed. With just 1,000 cells in each adult worm (not including germ cells), researchers are able to understand and follow the developmental fate of every individual cell in the organism.

Sinclair Stammers/Science Photo Library

Above: Light micrograph of *C. elegans*

Are there other model organisms that you would really like to have seen succeed that just didn't make it?

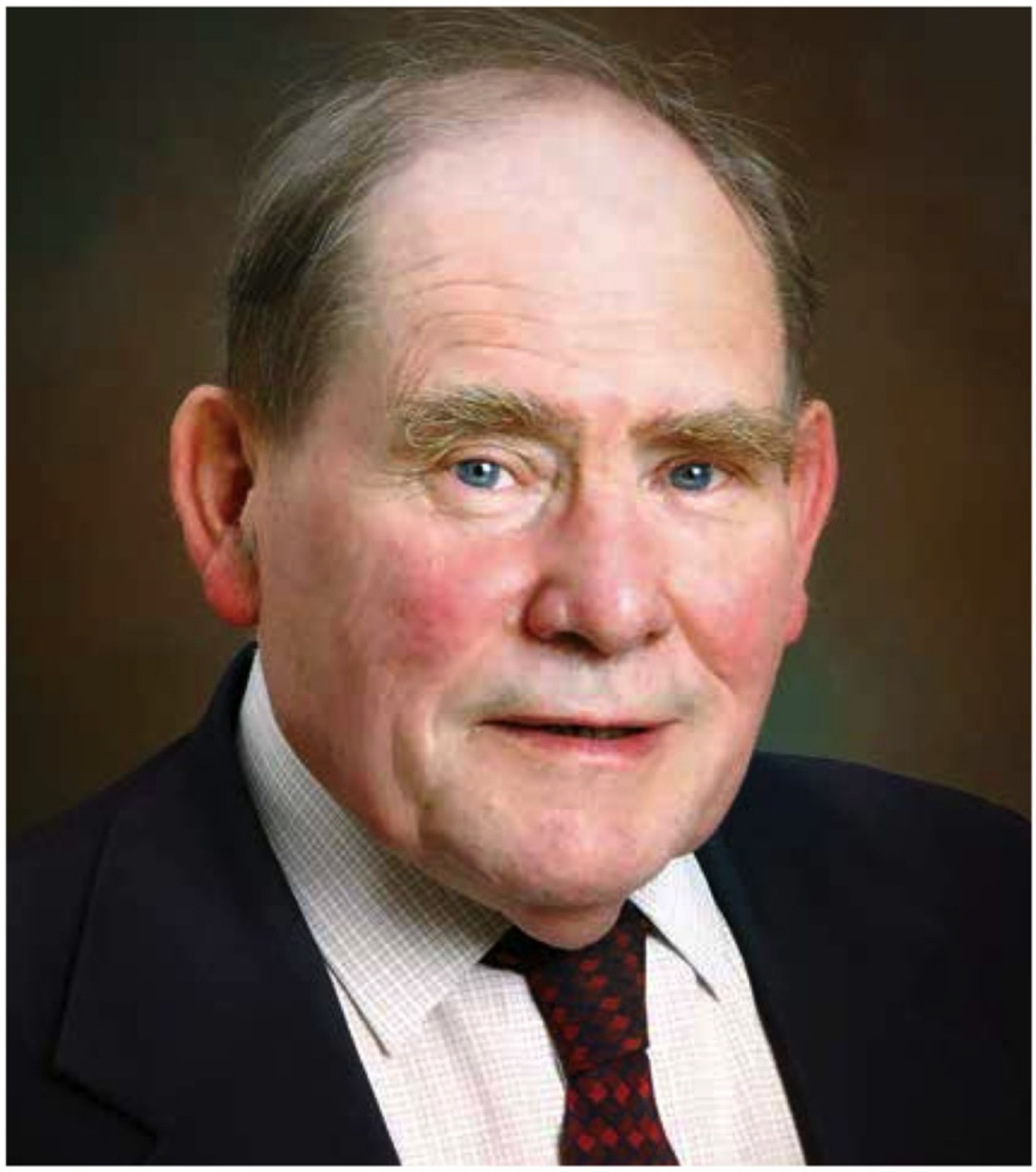
The one that I think is particularly sad is this amoeba called *Naegleria*, which we now know from its genome is a terrific basal eukaryote and does all sorts of interesting things, as amoeba go. It has features superior to *Dictyostelium*.

The trouble with *Naegleria* is that it can kill you by eating your brain. So people never really took to it...

It's the centenary of the Genetics Society, so we're celebrating 100 years of genetics. In the whole field of genetics what discoveries stand out for you over the last hundred years?

Oh, any number of things. The establishment of chromosome theory and heredity; what Thomas Hunt Morgan did putting the genetics together with the cells. It's a pretty heroic story to go through. Then people start being able to do molecular genetics on fungi, like [George] Beadle and [Edward] Tatum with their idea of 'one gene for one enzyme'. Then you move into a whole other layer with the DNA double helix and genetic code, and understanding the basics of transcription and translation.

"There are whole bits of the *C. elegans* nervous system and sensory organs – and we don't know what they are for"



Salk Institute for Biological Studies

Sydney Brenner, the pioneer of *C. elegans* research, sparked Jonathan Hodgkin's interest in the nematode. Brenner died this year aged 92

Then other important things were happening at the same time – for example, the idea that the genome is malleable and has mobile elements, which is down to Barbara McClintock. All of that is amazing. And it relied on model organisms – Morgan with flies, McClintock working with maize, Beadle and Tatum with the mold *Neurospora*.

Subsequently, all the people working on the phage and with *Escherichia coli* worked out molecular genetics – the ability to clone and amplify DNA was fantastically important, because that really allowed us to get into the biochemistry of it all. And that was all dependent on the ability to sequence DNA, which was down to Fred Sanger and others. This just got more and more efficient and then all of it was succeeded into the whole genetics revolution, which was and continues to be quite extraordinary, and changes everything.

What do you think is going to be the most exciting development over the next 10 to 20 years?

I think a lot is going to come out of the large-scale genome analyses people are doing. At the moment everybody is basically drowning in data and you have to say that a lot of what has come out has been disappointing. But people should not despair.

Do you think that's just the bottom of an exponential curve that will come?

Yes, I think it's going to come. I think there is a wood and trees problem, particularly with phenomena that we can see are very, very multigenic. However, I think people will get through that and we will see that you can understand what's going on by focusing on a few of the key players.

What do you think about the capacity we now have to interfere with our genomes and change them? Do you think that's an exciting opportunity? Is there anything that worries you about that?

I think that it's tremendously exciting. I think that it's also tremendously worrying and that a lot of this is going to happen willy-nilly, and we just have to live with this. The human race is not a static entity.

This technology is not going to go away, either. Coupled with what we were just saying about complexity, this means a lot of these genetic changes that people hope will make their baby wonderful – it's going to be totally different. Not totally unpredictable, but there are going to be huge numbers of unpredictable consequences.

"At the moment everybody is drowning in data, and you have to say that a lot of what has come out has been disappointing. But people should not despair"

Steve Gschmeissner/Science Photo Library; Kateryna Kon/Science Photo Library

Sex determination in *C. elegans* worms

C. elegans is unusual among nematodes in that individuals are either males (XX) or hermaphrodites (XO) that can self-fertilise. Males can inseminate hermaphrodites, which will preferentially use male sperm rather than their own male gametes. Hodgkin's work unpicked the regulatory cascade of genes that control whether a worm develops male or hermaphrodite characteristics. He identified that mutation of the tra-1 gene can completely switch an individual's sexual phenotype.

Above: SEM of *C. elegans*

Left: Illustration of *Naegleria*. The amoeba's brain-eating capabilities put researchers off using it as a model organism

People seem to often think of genetics as being deterministic and I think that's a big mistake because it's probabilistic. I think that's quite a challenge to discuss with people who don't really know about genetic principles.

It certainly is. Putting things to lay people is always difficult whatever area you're in, but the public and politicians are not good about thinking about probability, nor risks. We have obviously seen this with climate change and other environmental issues – you're dealing with chances, you're not dealing with certainties.

You've spent most of your career staring down a microscope at these tiny *C. elegans* worms. You can hear in the way you talk about them that you still have a huge passion for them. What is it about these worms that fosters that?

Simply the fact that there's something new every day after all these years. But also because the worm grows so fast – three days' generation time – you can think of something, experiment and get a result in a few days. It's the practicality of the worm that has a big appeal: the economy and the lack of ethical issues.

And you can see so much because they are transparent...

Yes, they are kind of fun to look at. We now have this enormous body of knowledge on them. There's also a huge amount we don't understand. It's just very satisfying, going on doing experiments, confirming things.

If somebody gave you £10m to work on something new or something that you maybe had not had time to pursue in the past, what do you think you might do?

There are really ambitious things that you can think about pursuing – doing a very large amount of genome editing to try to make a 'minimal worm' with as few genes as possible, for example. People are doing some of that already and it is a fascinating way to go.

You could also try to do more in the way of humanising the worm. Sticking in human genes or human pathways so that you could then study them in this system.

One simple thing that is bugging me at the moment is almost everything we do is looking at worms behaving in a two-dimensional sheet, whereas that's not their real environment. They live in a three-dimensional world. There are whole bits of the nervous system and sensory organs – and we don't know what they are for.

All these scientists have been beavering away for years on this tiny worm and there's still so much that we don't know. If you widen that view out to the rest of the other model organisms, and then of course all the other organisms on Earth, and then humans, you can see that biology has a really long way to go.

It does. One of the conclusions from that is that the only organism we are going to achieve any kind of complete understanding of is probably humans.

What would you do if you were starting out again?

One thing would be to work on something with practical utility, such as tuberculosis. I think diseases are wonderful ways into biology, but they are also important.

The other would be to get back to the large-scale problem that really got me into this business in the first place, which is how you genetically encode complex behaviour. The dog genome projects are great because dogs are so various in their behaviour and cognition. You have the genetics, you have the animals and you have enthusiasm. I think it's actually going to tell us some significant things.

And they'd be such wonderful creatures to look at every day as well...

Yes, exactly!

Accelerating evolution

Artificial gene drives are a way of spreading genetic changes through a population quickly – for example, to make large numbers of wild mosquitos infertile or unable to carry malaria. **Bruce Whitelaw** and **Gus McFarlane** explain how this technology works, and how it could be used in conservation and agriculture as well as public health

It was the work of Gregor Mendel and Charles Darwin that revealed the fundamental mechanisms of genetic inheritance. Mendel observed consistent patterns of inheritance from parents to offspring and Darwin's theory of natural selection illustrated how traits are selected over time based on fitness.

Gene drives may offer a more cost-effective, humane and species-specific alternative for controlling invasive pests

However, we now know inheritance does not always follow the rules. In some cases the odds of a particular gene being transmitted to the next generation can be heavily skewed. Genetic elements that manage to beat the odds by being passed on more than half the time are known as 'gene drives', and this numerical advantage enables them to spread through populations even if they reduce an individual animal or plant's fitness.

Gene drives evolve in sexually reproducing species due to the genetic conflict that occurs between genes in an organism, enabling them to gain an advantage over their genetic competition and increase their likelihood of being passed to future generations. While most genes are transmitted to 50% of the offspring, gene drives manage to be transmitted to more than 50% of the offspring – that could be just 50.01% or a full 100%.

Broadly speaking there are two main strategies genes can use to achieve 'drive'. The first is interference, whereby the gene gains an advantage by disrupting the transmission of an alternative gene. For example, a gene in a diploid organism could reduce the fitness of the 50% of sperm or eggs that receive the alternative gene during the process of gametogenesis, thereby increasing

its own chance of success and reproduction in the next generation.

The second method is by overreplication. These gene drives bias their transmission to the next generation by being replicated more than other genes in an animal. Homing endonuclease genes are a good example: these cut DNA and get copied into the cut site as part of the repair process, increasing their abundance in the animal's genome[1].

LEARNING TO DRIVE

It was the study of naturally occurring gene drives that lead Austin Burt of Imperial College London to first propose that synthetic gene drives could be used to alter or suppress wild animal populations[2].

That was over a decade ago, and the genome editing tools available at the time were not useful in many organisms or suffered from evolutionary instability. Fast forward to 2019 and the blockbuster genome editing tool known as CRISPR has enabled scientists to engineer synthetic gene drives in animals that could profoundly benefit public health, agriculture and the environment.

CRISPR gene editing uses a Cas enzyme, which works like a pair of a molecular scissors to cut DNA. A guide RNA guides the Cas enzyme to a targeted DNA sequence in the genome[3]. In 2014 Kevin Esvelt and his team at MIT outlined a technically feasible way to develop CRISPR-based gene drives[4] and this approach has led to a flurry of research activity and media attention.

The most investigated form of CRISPR-based gene drive is known as a homing gene drive. This works by cutting a target DNA sequence in an animal's genome and then copying or 'homing' itself into the cut site. A CRISPR-based homing gene drive is essentially an engineered overreplication gene drive.

To build this system an animal is engineered with a gene drive cassette that encodes the two components of CRISPR: the Cas enzyme and guide RNA (see diagram, p21). These components, when expressed from one allele, then cut the sister allele on the other (homologous) chromosome.

After the sister allele on the homologous chromosome is cut, a cellular process known as homologous recombination results in the gene drive cassette (and any additional genetic payload included in it) being copied onto the homologous chromosome.

This means that both sets of chromosomes have copies of the gene drive cassette – and any animal with two copies of a gene is guaranteed to pass it on to all their offspring. As well as the CRISPR machinery, the gene drive cassette can be engineered to deliver additional DNA sequences with a desired trait.

In the offspring generation, the homing process occurs again and will do so in all subsequent generations, resulting in the gene drive spreading through the targeted population[4].

BEYOND MOSQUITOES

To date CRISPR-based homing gene drives have been developed in yeast, fruit flies, two species of malaria-carrying mosquitoes and most recently in mice[5,6]. Most of the research on CRISPR gene drives thus far has focused on controlling populations of mosquito as vectors of human disease and significant progress has been made towards achieving this goal. Demonstrations of the technology in other species have primarily been proof-of-concept experiments, which have widened the scope of the technology's potential applications.

Another potential application of gene drives is to control invasive pests. Invasive vertebrate pests, such as cane toads and rabbits in Australia, grey squirrels in the UK, possums in New Zealand and rodents around the globe cause significant damage to the environment, and incur economic and social costs. Control measures include shooting, poisoning, trapping and the release of biological agents, which are largely inadequate and costly, and often lead to unwanted suffering in both target and non-target species.

Gene drives may offer a more cost-effective, humane and species-specific alternative. In most pest species, female procreative capacity is responsible for maintaining the overall population size and so an efficient means of population suppression is to bias the sex ratio in favour of males. A grossly male breeding population will result in a population decline, while an all-male breeding population would lead to eradication.

A homing-based gene drive can achieve this with a gene drive cassette targeted to disrupt the coding sequence of an essential female fertility gene[5]. Males would be unaffected by loss of the female fertility gene, while all females that inherit the drive would be infertile.

Gene drives could also be used to rescue threatened or endangered animals. For instance chronic wasting disease (CWD) is a form of prion disease in cervids that affects primarily deer, elk and moose. The infectious prions responsible for CWD are caused by misfolding and aggregation of a normal, cellular prion protein (PrP^C) and are spread

Scientists are working to develop gene drives that are inherently self-limiting – that is, they only stay in a population transiently and could be localised to targeted populations

Gus McFarlane AMRSB (left) and Bruce Whitelaw FRSB from the Roslin Institute

through saliva, urine and faeces. Once an animal is infected, misfolded prion protein builds up in the brain, causing neuronal loss and eventually leading to death. In some states in northern USA, prevalence of CWD in deer is up to 35% in free-ranging populations and 90% in captive deer.

Studies in rodents and large animals have shown that animals do not require PrP[7] and that gene drives that remove or 'knock out' the PrP gene could be used to rescue infected cervid populations from this highly infectious disease. However, the long generation interval in cervids would mean the drive spreads far more slowly through the population than in insect applications, for example.

RESCUING AMPHIBIANS

Gene drives could also be applied to rescue threatened amphibians from chytridiomycosis. Chytridiomycosis is the disease caused by the fungus *Batrachochytrium dendrobatidis*, which has been implicated in mass die-offs and the extinction of hundreds of frog species since the 1990s, and threatens up to 50% of amphibians.

As the fungus reproduces mostly asexually, it cannot be controlled with a gene drive itself. However, resistance to *B. dendrobatidis* infection varies both within and among amphibian species. Major histocompatibility complex (MHC) peptides play an important role in the innate immune system of vertebrates and a specific MHC allele in the lowland leopard frog has been shown to increase survival of infected individuals[8].

Gene drive could be used to spread the lowland leopard frog's resistant MHC allele through threatened amphibian populations, rescuing species from this killer fungus and potentially saving them from extinction. Careful consideration in the gene drive design would be required to ensure the gene drive does not impair the function of key immune system genes.

Potential gene drives in aqua- and agriculture

In Norway the total cost of sea lice to the aquaculture industry is around £400m per year, and treatments involve chemicals that damage marine ecosystems, affect fish appetite and growth, and mean treated fish can't be sold for several weeks after treatment. There is also resistance among lice to the three major classes of chemicals used. Self-limiting gene drives could be deployed to locally suppress lice populations in fish farms without affecting the broader marine ecosystem.

The salmon louse *(Lepeophtheirus salmonis), a species of sea louse*

Another pest species that has significant economic and welfare implications for animal agriculture is the New World screwworm (NWS) fly. NWS causes myiasis, a parasitic infestation of warm-blooded animals as a result of the flies' larvae growing inside the host and feeding on its flesh. The screwworm is found in all South American countries except Chile and has an overwhelming impact on livestock farming throughout the region. Wildlife is also threatened, especially endangered species. The US is considered NWS-free after a 50-year eradication programme estimated to have cost £1bn. As a potentially quicker and cheaper solution the nations of South America could deploy self-limiting gene drives to locally suppress NWS or a self-perpetuating drive to eradicate the pest from the entire continent, potentially saving wildlife from NWS infestation and increasing agricultural productivity.

Gene drives could be applied to protect cervids such as moose from chronic wasting disease, although it could take decades to spread through populations

The main concern with homing gene drive strategies is that these self-perpetuating genetic elements can, in theory, spread indefinitely. There are, however, scenarios and strategies to prevent the duration and extent of this.

First, the spread would be limited by naturally arising resistant alleles that prevent CRISPR from recognising and cutting its target site. These resistant alleles could exist in the population prior to release or evolve when an error in the DNA repair process occurs and a CRISPR-mediated cut is repaired with a new functional DNA sequence (which the CRISPR guide RNA in future generations then does not recognise).

If a gene drive was not stopped by naturally arising resistance, there are 'stop' buttons available, theoretically. Gene drives can be inactivated by the release of animals with engineered resistant alleles or even with a 'reversal gene drive' that immunises the animal against the original drive.

However, these reactive stop buttons are not ideal. A more proactive approach is needed and scientists are working to develop gene drives that are inherently self-limiting – that is, they only stay in a population transiently and could be localised to targeted populations.

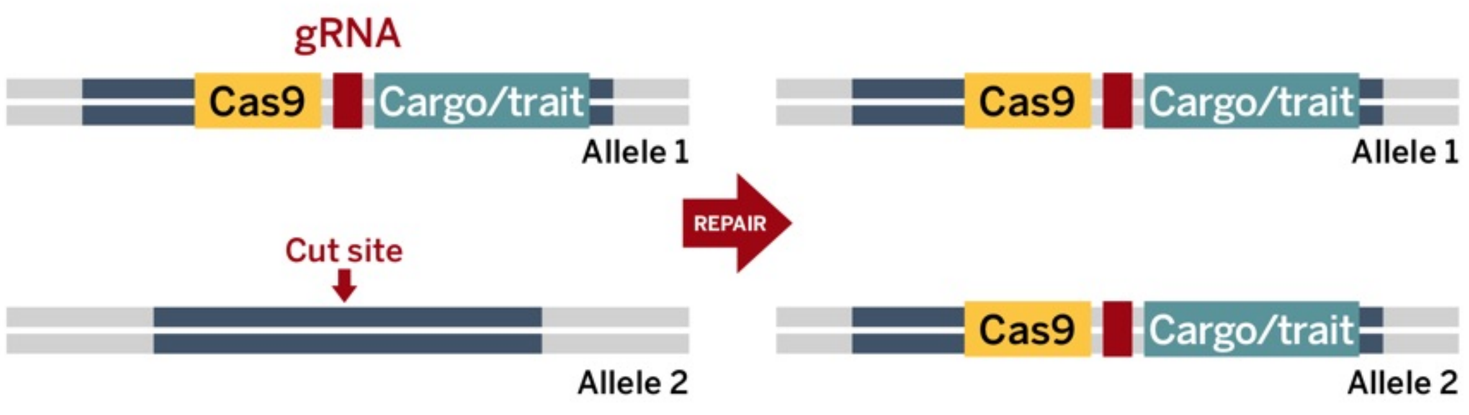
Several self-limiting gene drive concepts have been proposed and it is hoped these systems will soon be realised[9]. One type is a so-called 'daisy-chain drive': with this approach the CRISPR components of the gene drive are split up and

The homing gene drive

Ensuring genetic modifications are on both chromosomes of a pair means it will spread rapidly through a population

A 'gene drive cassette' is inserted into an organism's genome on one chromosome of a homologous pair.

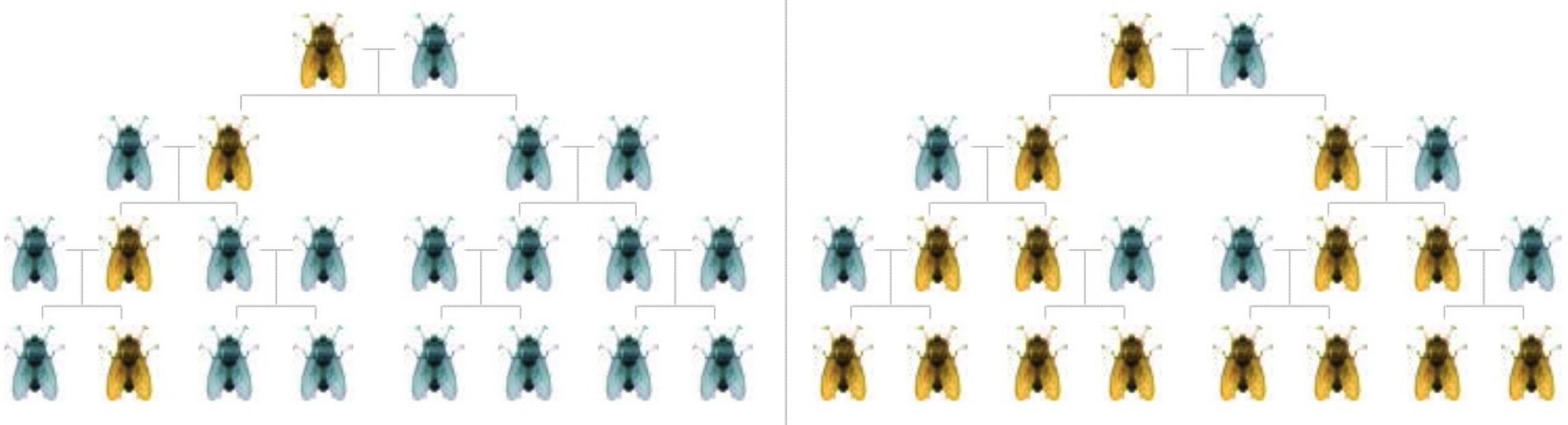
When the Cas9 and guide RNA are expressed, together they make a cut at the same location on the other chromosome of the pair.



The cell repairs the cut by copying the sequence at this location from the other chromosome, including the cassette.

With the cassette now on both chromosomes, it is almost certain to be passed on to all offspring.

The process repeats in the cells of the next generation, with the cassette copying itself so it is on both the paternal and maternal chromosome.



scattered throughout the genome so that none of them can be copied on its own. Element A can only copy itself if element B is present, and element B can only copy itself if element C is present. And element C, crucially, cannot copy itself at all – it can only be passed on to offspring at the normal rate of 50%.

If daisy-chain animals carrying all three elements were released, all the offspring will inherit element A and B, but only half will inherit element C. In the following generation element B and A will spread, but C will gradually die out. Once it does, B will start to disappear and finally A will too.

FUTURE POTENTIAL

If robust self-limiting gene drives can be developed, it puts the power in the hands of communities to deploy a gene drive locally, avoiding the need for highly complex geopolitical agreements that will be required for self-perpetuating gene drive systems.

With the realisation of self-limiting gene drives, this technology would be more amenable to applications in animal agriculture and aquaculture, such as the pressing issue of sea lice in fish farming (see 'Potential gene drives in aqua- and agriculture', above left) or the eradication of the New World screwworm.

Although gene drive technology still faces significant scientific, political and social hurdles, we are optimistic of its future potential and as such have chosen to highlight prospective applications of the technology in this article. However, it must be noted that before any of these proposed applications are deployed there is a requirement for in-depth analysis of the ecological implications, as well as the need for broad community engagement with those that may be affected by the release of a gene drive.

Each potential application should be considered on a case-by-case basis, but with the rapid progress in this field, it is hoped the risks associated with current homing gene drive strategies are reduced with the realisation of self-limiting gene drive approaches.

For the first time we have the makings of a technology that could allow us to overcome the limitations imposed by conventional genetic inheritance and utilise molecular biology to spread beneficial traits through wild animal populations. Both Mendel and Darwin would certainly be astounded by how far our understanding has come and the benefits gene drives could offer our society and the environment.

Bruce Whitelaw is deputy director and director of partnerships at the Roslin Institute and professor of animal biotechnology at the Royal (Dick) School of Veterinary Studies. He is currently establishing robust methodology for genome editing in animal systems.

Gus McFarlane is a doctoral student at the Roslin Institute focused on developing CRISPR-based gene drive strategies for controlling invasive vertebrate pests. He is interested in the application of genome editing tools to improve the welfare and performance of livestock.

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Early developers

Marsupials are born underdeveloped and spend a long time suckling and developing in their mother's pouch. **Kevin Nicholas** explains how the complex signalling molecules in marsupial milk could help inform treatments for human babies born prematurely

Significantly preterm and low birth weight babies face acute and chronic health challenges, largely due to the limited development of their lungs, gut and brain. Disruption to the timing of development in these babies can increase the risk of disease later in life and is exacerbated if growth during the early stages of treatment is accelerated too aggressively[1].

The availability of breast milk is critical to successful therapy for preterm babies – in particular, access to colostrum, the first form of milk produced immediately following delivery of the newborn. However, after the birth of a significantly preterm baby mothers can face challenges breastfeeding successfully, leaving either formula or pasteurised donor milk the only options available.

The nutrition provided by mature milk is inadequate and a fortifier is used to improve the health outcomes. New approaches are required to manage the early stages of treatment, with a particular focus on improving the function of organs without encouraging excessive growth.

GESTATING JOEYS

Our approach exploits the reproductive strategy of the tammar wallaby, an Australian marsupial[2]. They have a short gestation of just 26 days and give birth to altricial young considerably more immature than a preterm baby: the development of the brain is equivalent to a 50-day-old human foetus and there is insufficient alveolar development in the lungs to sustain respiration. For the first two weeks the neonate respires through its skin and for the first 100 days is attached to the teat, and could in many ways be thought of as a foetus, but in a pouch rather than in the uterus.

During early lactation in the tammar the immature organs that are necessary for survival develop rapidly

Tammar neonates (right) receive milk appropriate for their development but human milk is often not sufficient for significantly preterm babies (below)

Dave Watts/NPL

Both tammar newborns and human preterm babies receive milk to sustain their development. However, while preterm babies will face acute and chronic health challenges, tammar neonates receive milk that is exclusively appropriate for their growth and development into healthy young.

We are asking whether an understanding of the milk bioactivity provided to the tammar neonate can inform the development of new milk fortifiers for preterm babies.

Could a comparative approach, focused on the signal molecules presented prior to lactation in the human and in the milk during the early stage of lactation in the marsupial, be useful to better understand the specific signals that regulate development? And could new insights in this area lead to new approaches to improve outcomes for preterm and low birth weight babies?

EARLY DAYS

During early lactation in the tammar – particularly in the first 100 days – the immature organs that are necessary for survival, such as the respiratory system, gut, lymphoid tissues and nervous system, including brain and spinal cord, develop rapidly[3–7].

During this time the mother provides a milk that slows growth and progressively changes composition to signal the development of organs. When the young are more independent, the nutritional content of the milk changes to stimulate growth. This is exactly the strategy required in neonatal intensive care units (NICUs) for preterm babies.

Although human milk does change composition during lactation, many signalling molecules required for development are most likely presented to the human foetus by the placenta and amniotic fluid prior to parturition (Fig 1). Therefore a comparative approach that focuses on the signal molecules presented prior to lactation in the human and in the milk during the early stage of lactation in the marsupial may be useful to better identify the specific signals that regulate

development. Generally, the regulatory mechanisms controlling the great majority of physiological processes have been conserved during evolution, although the timing and mechanism for delivering these processes may differ between species of mammals.

TESTING TAMMARS

The role of tammar milk in lung development has been examined using embryonic lungs from mice[8]. The embryonic lungs were cultured in media containing milk collected at key time points during tammar lactation.

The lungs showed increased branching morphogenesis when incubated with milk collected between day 40 and day 100 of lactation, and reduced lung development when incubated in media with milk from later stages of lactation. In addition, day-60 milk significantly upregulated a number of marker genes for key developmental processes and specialised cell types[8]. This effect was significantly reduced in milk collected after day 100 of lactation.

The concept was studied further with an *in vivo* approach using cross-fostering experiments[8]. Here, 25-day-old joeys were fostered progressively to a series of mothers at day 15 of lactation so that the young only received milk from day 15 to 25 of lactation for a period of 20 days.

The expression of marker genes related to branching morphogenesis, alveolisation, and

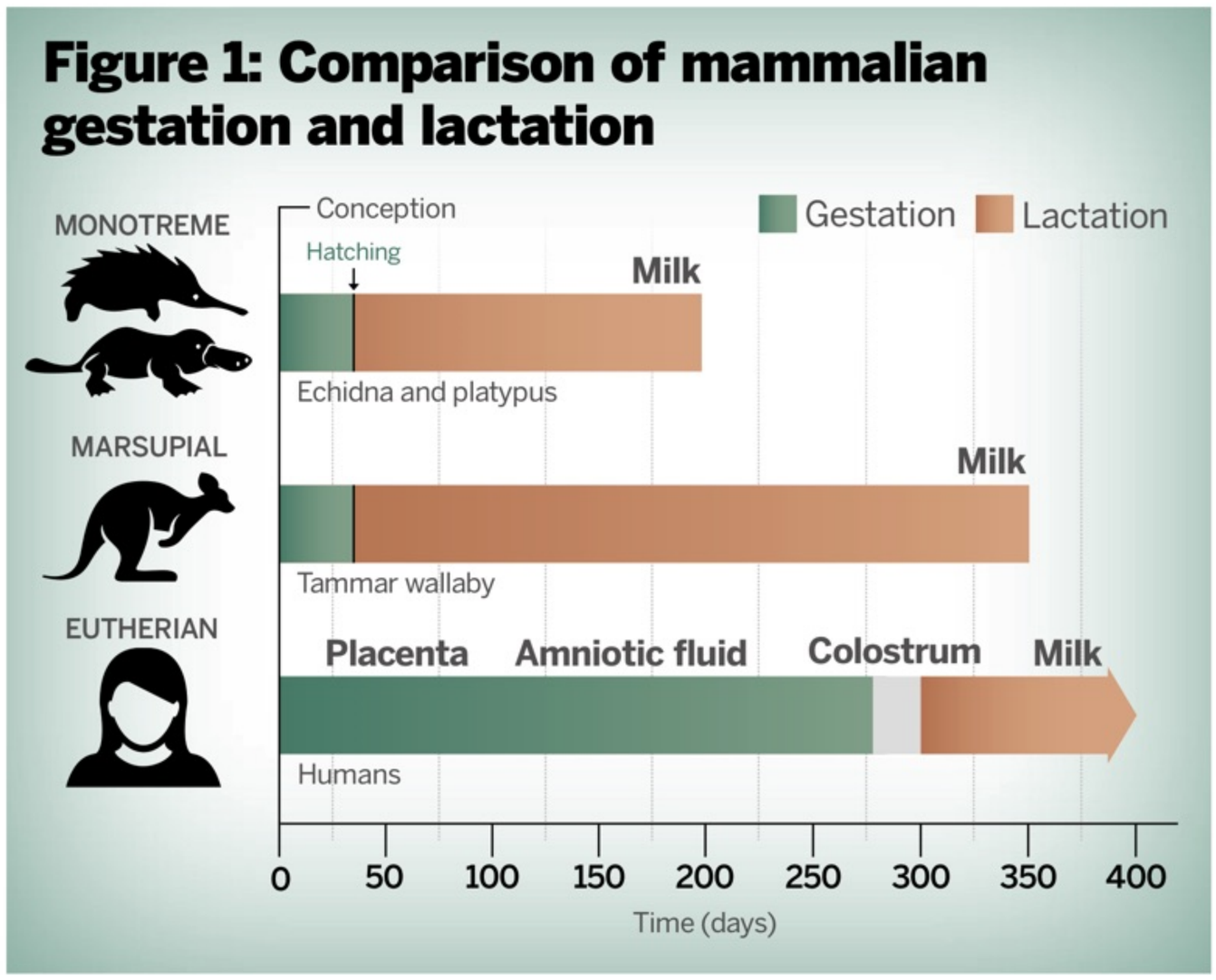

Fig 1: Marsupials and monotremes give birth to far less developed young than humans and provide bioactives via milk earlier in the developmental process

presence of terminal and airway epithelia were significantly reduced in lungs from fostered-pouch young compared with lungs from control-pouch young.

Previous studies on wallabies have also shown dramatic changes in gut morphology[9] occur in the suckled young and take place while the young are still in the pouch. There is also significant development of the central nervous system in the tammar neonate, but further work is required to determine whether milk has any role in this process.

COMPARING DATA

The putative signalling molecules in milk received by the tammar young during early lactation may help inform us about the role of similar signals for tissue development in the human foetus/neonate by the placenta, amniotic fluid, colostrum and milk. Milk proteins, peptides and microRNAs are of particular interest for their role in signalling development.

Databases showing gene expression in the tammar mammary gland during various stages of development of the neonate may prove useful when interrogating similar datasets derived from cells in human colostrum, milk, placenta and amniotic fluid.

In a study in 2016[10] we used a minimally invasive approach to get a snapshot of gene expression in the cells present in colostrum and breast milk at specific time points during lactation. The mammary glands from wallabies during the first 100 days post-partum were also analysed and the genes expressed identified. This dataset was compared with similar datasets for human milk cells collected at day 30 of lactation, cells from colostrum, and other publicly available genomic datasets for human placenta and amniotic fluid. Importantly, the only genes analysed in this study were expressed exclusively at the indicated time point and were identified as coding for secreted proteins.

The data showed about 165 common genes expressed in the tammar mammary gland and all the other databases, but the most significant overlap was between the tammar mammary gland and the

There is significant development of the joey's central nervous system while in the pouch

The evolution of lactation

Short-beaked echidna *(Tachyglossus aculeatus)*, an egg-laying monotreme

Since the appearance of the aplacental, egg-laying monotremes 200 million years ago there has been extensive adaptation in reproduction and particularly lactational strategies.

Mammals that give birth to live young without eggs (Theria) split into the Metatheria (Marsupialia) and Eutheria (Placentalia) lineages more than 140 million years ago.

Eutherians (such as humans) have a well-developed placenta and a long gestation that leads to the birth of a relatively well-developed young. The length of lactation is often similar to the length of gestation.

In contrast, marsupials have a simple placenta, a short gestation and the neonate is very altricial (underdeveloped). The duration of lactation is long relative to the pregnancy, and the milk progressively changes composition to provide appropriate nutrition and control development of the neonate. The neonate's body temperature is maintained in the pouch and the mother cleans any waste excretion.

colostrum. Further analysis of colostrum will be required to establish the presence of any putative bioactive proteins/peptides, but our understanding of the evolution of lactation supports an explanation for this observation: the brief transient secretion of colostrum after birth is only seen in eutherians and is the most comparable form of human lactation to that of lactation in marsupials.

As evolution is correlated with increased gestation in humans (and all eutherian mammals), a provocative hypothesis is that if evolution continues in this direction, perhaps in 50 million years eutherians will no longer secrete colostrum and the majority of these critical signalling molecules will be presented preterm to the foetus by the placenta and amniotic fluid.

This comparative approach, although preliminary at this stage, has enormous potential. It is clear the marsupial provides a unique opportunity to more easily identify the bioactives that potentially play a role in early development of the eutherian foetus.

The regulation of the lactation cycle in the tammar wallaby is complex and fascinating, and has challenged scientists for many decades – and it is the timed delivery of bioactives in the milk and its role in the development of the suckling young that are of paramount interest. From a practical perspective, future comparative studies will focus on human colostrum to determine if any of the bioactives secreted could be used in therapeutic approaches to improve health outcomes in significantly preterm babies.

The next generation of fortifiers used in the NICU may benefit from delivering a combination of improved nutrition and human signalling bioactives that have been identified in marsupials and shown to direct improved function of tissues such as the gut, lung and brain.

Kevin Nicholas is an adjunct professor at the Monash Institute of Pharmaceutical Sciences and a Professorial Fellow in the School of Biosciences, University of Melbourne. His interests focus on exploiting an understanding of the evolution of lactation to better identify the function and delivery of milk bioactives.

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Sensing success at iGEM

A team of scientists from the University of Nottingham explain their gold medal-winning competition project – a novel system to detect botulinum toxins in food

Every October thousands of students from around the world gather in Boston, USA, for one of the largest science competitions in the world, the International Genetically Engineered Machine Competition (iGEM). The competition brings together 375 teams from 45 different countries and is the closest thing there is to the Science Olympics.

Multidisciplinary teams (some made up of students still at high school) work over the summer to design, build and test a system using interchangeable DNA parts. The teams come together in October to present their work and compete at the annual Giant Jamboree in Boston, attended by more than 6,000 people.

Teams use and develop BioBricks – standardised, open-source genetic components that form an enormous registry of parts available to all entrants. Working with BioBricks poses an exciting challenge for the undergraduates who would otherwise not have the opportunity to use this technology. It also helps to further standardise the tools of synthetic biology.

The teams look to tackle real-world problems, in their communities or beyond, such as rapid diagnosis of disease, antibiotic resistance or climate breakdown. Projects this year included magnetic bacteria engineered to pull plastic particles from the sea, an 'astropharmacy' to endlessly produce drugs in space, wearable living opioid detectors and 'robotised' algal cells. Many teams in the past have gone on to start successful businesses.

This year our group of undergraduate students from the University of Nottingham came together to develop a system to 'sniff out' *Clostridium botulinum* when food preservation and packaging methods fail and allow growth of the dangerous bacteria. These bacteria can cause a type of food poisoning known as botulism (see 'Fatally flawed foodstuffs', p29) that can result in paralysis and even death.

C. botulinum is an anaerobic bacterium, meaning it can grow in conditions that completely lack oxygen. The organism is notorious for producing the deadly botulinum neurotoxin. There are seven different types of the botulinum toxin: A, B, C1, D, E, F and G – human botulism is only caused by types A, B, E and, rarely, type F. The toxin, when in the nervous system, prevents the release of messenger chemicals, resulting in paralysis.

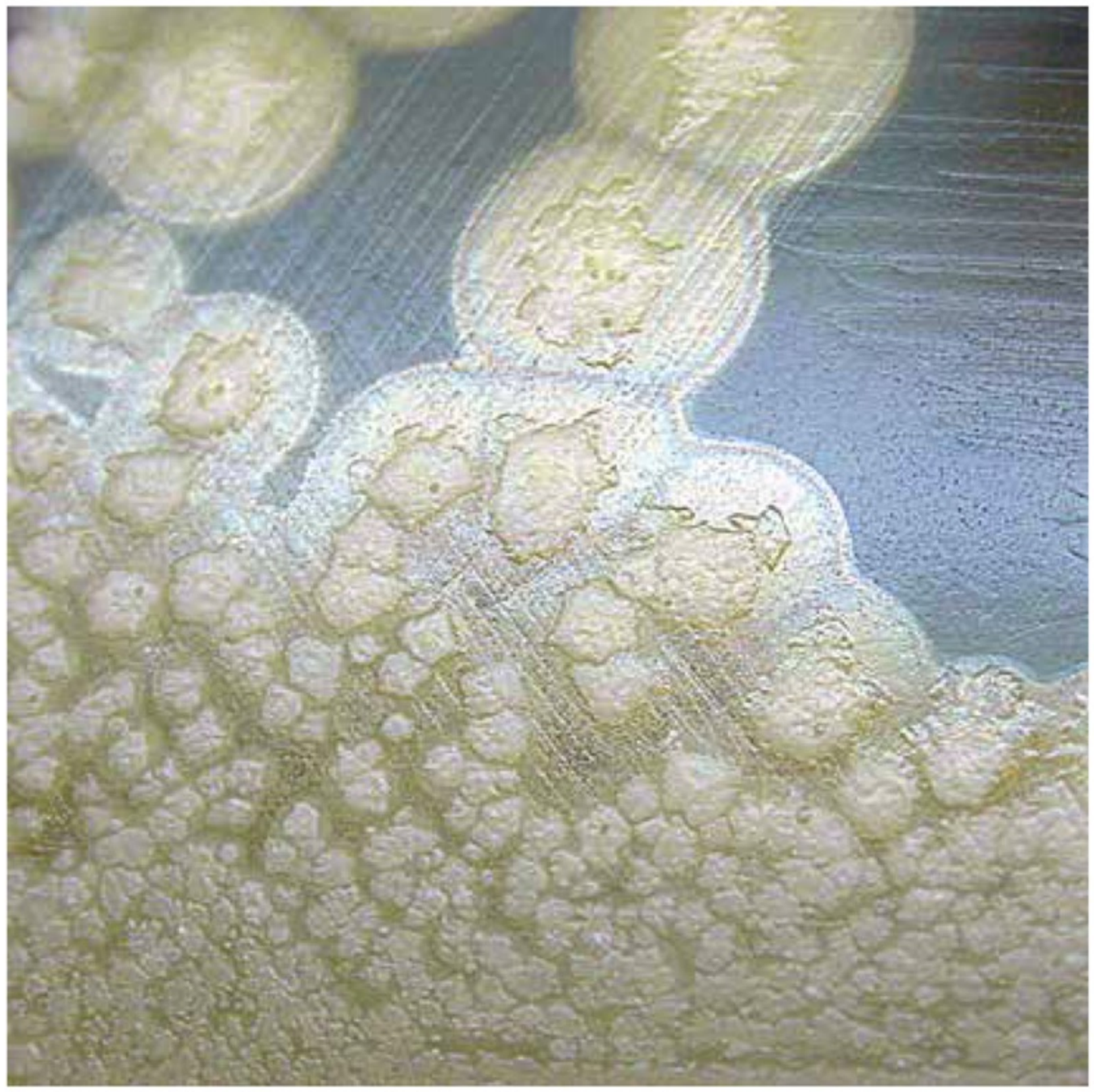
Infection with *C. botulinum* or ingestion of the toxin causes the disease botulism, a serious illness where paralysis normally spreads from the facial muscles and can be fatal if breathing muscles are affected.

The *C. botulinum* bacterium can also form spores that are highly resistant to harsh environments. Consequently, when they contaminate food that has been improperly prepared, the spores can germinate into toxin-producing bacterial cells that cause botulism when ingested.

The team aims to provide a cheaper and faster alternative to current food-testing methods and could replace the need for animal testing

THE CHALLENGE OF CHALLENGE TESTING

Food companies have to subject their products to rigorous trials to determine expiry dates in a process called challenge testing. This type of testing involves injecting test food with bacteria in a laboratory to determine whether the food-preservation method reliably prevents bacterial growth. After inoculation, the food is kept for a certain period of time under specific storage conditions before samples are tested. The gold



Centers for Disease Control and Prevention

standard for detecting the botulinum toxin protein is known as the enzyme-linked immunosorbent assay (ELISA).

The assay determines whether the bacteria have been able to grow and produce the toxin, and can be used to determine the subsequent shelf life of that product. However, challenge testing is very expensive, as there are large amounts of food replicates involved, and the preparation and extraction of the toxin for the ELISA assay is complicated. Botulism outbreaks are estimated to cost the food industry about £25m for every person poisoned. Unfortunately, not all companies, especially smaller ones, can afford to undertake challenge testing.

Above: *Clostridium botulinum* growing on egg yolk agar

Above left: The Nottingham team. Top row from left: Yaseen Tengur, Alice Hodson, Millie Johnson, Saniya Crouch, Marta Marcheluk, Sami Rahman, Daniel Vaughan and James Abbott; bottom row, from left: Fiona Kemm and Jacob Gausden

Below: The team with their electronic 'nose' at iGEM

OUR IGEM ENTRY

In previous years Nottingham's iGEM teams have worked on projects involving bacterial security with *Escherichia coli* and engineered bacteriophages in the treatment of *Clostridium difficile* infections.

Our team this year comprised 10 science-loving undergraduates studying a range of degrees, from biotechnology to computer science and mathematics. We entered iGEM to develop our technical skills, learn more about synthetic biology and experience life in academia. Our project used just over 40 iGEM parts to develop a strain of bacteria that could be used to safely monitor the likelihood of botulinum neurotoxin production in food. For our proof-of-concept studies we used the rarely toxic surrogate strain *Clostridium sporogenes* in place of the highly toxic *C. botulinum*. The anaerobic *C. sporogenes* is already used in industry as a surrogate for *C. botulinum* due to its similarities to the pathogen.

The strain was modified to produce the volatile gas acetone in the presence of a transcription factor known as BotR, the signalling molecule that induces the bacterium to start producing the toxin. After the BotR gene was introduced to the bacteria a plasmid was introduced with reporter genes that gave off acetone when BotR was present in the cell.

The gas could then be detected using an electronic 'nose' designed and created by the team. Once the sensor detected the acetone it induced a voltage that could be converted to acetone concentration and displayed on an LED screen.

From old sausages to celebrity Botox

The name of the illness associated with *C. botulinum* poisoning, botulism, comes from the Latin for sausage, botulus, a common source of the disease when it was first described by German medical writer Justinus Kerner in 1820.

In addition to foodborne botulism, infant botulism occurs when young children ingest tiny amounts of botulinum spores, which would be harmless to older children and adults with a more developed immune system and gut microbiota. Natural foods such as honey can be a reservoir for botulinum spores, hence the recommendations to avoid giving honey to children under the age of one. Wound botulism is caused by botulinum spores entering the body through damaged skin and is most common in intravenous drug users.

Purified botulinum neurotoxin is the most acutely lethal known toxin on Earth – it is estimated one gram could kill up to one million people. The toxin blocks key neurotransmitters at the junction between neurones and muscles, causing paralysis of muscles including the respiratory muscles.

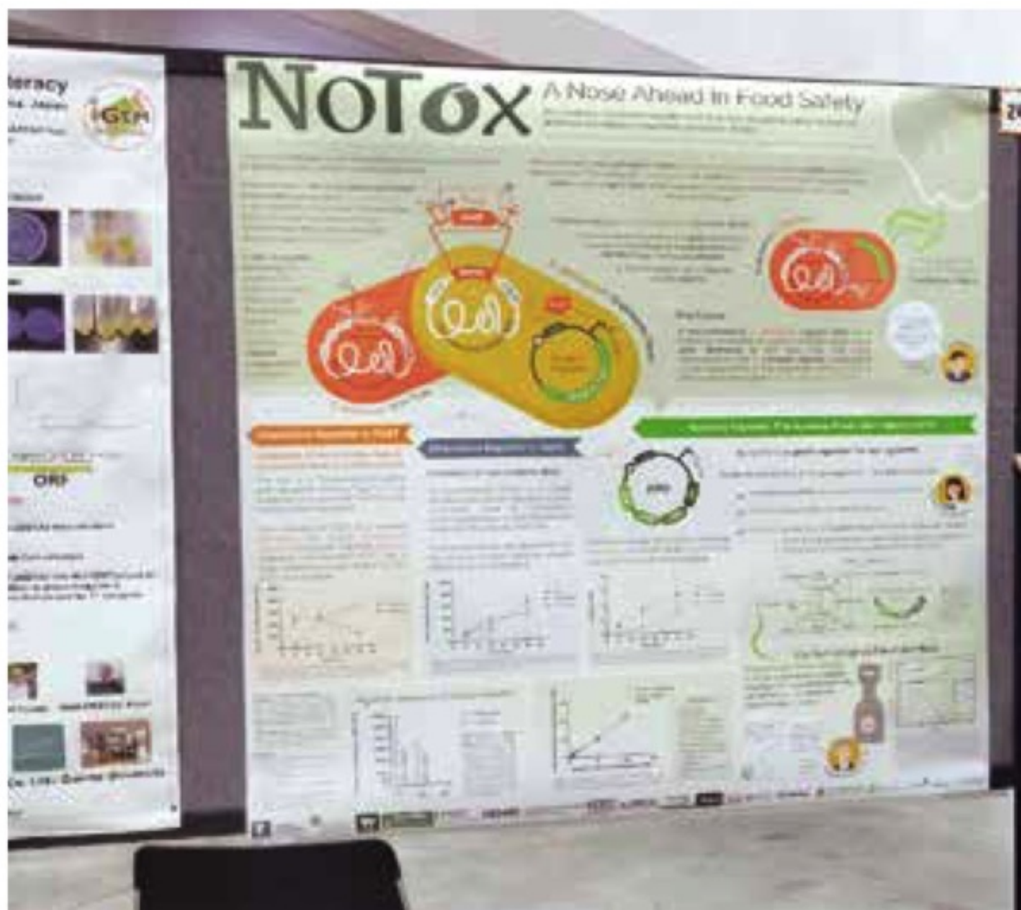
However, heavily diluted forms are used in the treatment of muscle spasms and in the popular cosmetic procedure known as Botox, where paralysis of facial muscles is used to smooth out lines and wrinkles.

Our mutant *C. sporogenes* model proved it is possible for BotR to drive expression of a reporter gene. This paves the way for using the same method to create a *C. botulinum* strain that produces acetone in place of the botulin toxin. The acetone could then be detected in the headspaces of inoculated food products that have modified atmospheres or are vacuum packed. The system could then be used to test whether food packaging will support the production of botulinum toxin, serving as proof of concept that reporter-strain technology can be useful in botulism prevention.

With this alternative method for detecting toxin production in food packaging, the team aims to provide a cheaper and faster alternative to current

Above: Millie Johnson in the laboratory and, below right, next to the Nottingham poster

Far right: The team with supervisor Professor Nigel Minton and Mike Peck, professor of applied bacteriology, second from left



Fatally flawed foodstuffs

Foodborne botulism is rare, but when it occurs it is serious (see 'From old sausages to celebrity Botox', left). Only 62 cases were formally recognised in the UK between 1922 and 2005, with the largest outbreak in 1989.

Contaminated hazelnut yoghurt resulted in the hospitalisation of 27 people and the shutdown of a major company. Yoghurt, being acidic, would usually inhibit *C. botulinum* growth, but a pre-roasted hazelnut mixture had been stored at room temperature for several months.

This allowed the bacteria to grow before being added to the yoghurt, which was assigned a 25-day use-by date.

An outbreak of foodborne botulism in 1982 caused what was at the time the largest recall of a product in the US Food and Drug Administration's history, requiring the mass recall of millions of cans of Alaskan salmon.

The cause was found to be a "small dented-in black spot and tiny hole" created by a specific type of can manufacturing machine used in multiple factories.

The defect allowed *C. botulinum* spores to contaminate the cans and the filling of the cans resealed the puncture holes, creating an anaerobic environment perfect for the bacteria to grow in.

ELISA food-testing methods and could replace the need for animal testing, which still takes place in many countries.

Better methods for detecting botulin toxin could also potentially help reduce food wastage by enabling food manufacturers to set more accurate expiry dates, reduce food packaging by helping food manufacturers to test eco-friendly packaging cheaply, and help smaller companies that are currently unable to carry out expensive challenge testing.

JAMBOREE TIME

The last hurdle for the Nottingham iGEM team was to demonstrate what they had achieved over the summer to the iGEM judges at the Jamboree. The Giant Jamboree is held over four days, with the first three devoted to judging hundreds of projects and an awards ceremony on the last.

Each team had to give a 20-minute presentation (plus five minutes of answering questions) and display their project on a scientific poster. Nottingham's project 'NoTox – a nose ahead in food safety' was presented on the first day by second-year undergraduate students Saniya Crouch, Millie Johnson, Alice Hodson and Jacob Gausden.

The end of the presentation marked the start of the poster judging period. The judges asked numerous questions including how we assembled our constructs and tested our reporter strain. The judges were particularly impressed with the team's self-designed and constructed electronic nose.

The remaining time at the Jamboree gave the Nottingham team the opportunity to attend plenty of other presentations and examine other teams' posters. The group from Nottingham especially enjoyed presentations by other university teams they had collaborated with, including Oxford, Newcastle, Sheffield and Manchester, as well as Carroll High School. When not watching presentations, we attended the Jamboree's careers fair, with biotechnology and synthetic biology companies represented, and workshops hosted by the likes of the FBI and NASA.

Finally came the closing ceremony and the results. All the hard work paid off, and Team Nottingham 2019 can now proudly boast a gold medal along with nominations for 'Best Food and Nutrition' and 'Best Integrated Human Practices'.

Team Nottingham would like to thank all the supervisors, sponsors and the organisers of the iGEM competition for their advice, support and contributions. The experience has been unique and a great success, but would not have been possible without the generous help of the large team of people supporting them at SBRC-Nottingham, University of Nottingham.

For more information on this and the other 13 UK teams at iGEM visit **www.igem.org/Team_List**, the iGEM website at **www.igem.org** and the Nottingham iGEM team website at **https://2019.igem.org/Team:Nottingham**

All the hard work paid off, and Team Nottingham 2019 can now proudly boast an iGEM gold medal

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The Motorcycle Diaries

For the last five years **Janelle Kaz** has combined her love of nature and motorcycles on a two-wheeled intercontinental conservation adventure. She gives *The Biologist* a taster of the latest leg of her trip, across Chile and Peru, where she meets groups helping to protect otters, armadillos and Andean cats

Nothing about seeking rare and endangered species on a long-distance motorcycle voyage is conventional, especially if you happen to be a woman riding solo through South America on a heritage bike.

My objective when on two wheels is to document wildlife and ecosystem protection. With a background in biology, and a number of years spent developing wildlife and environmental education curricula in Laos, I hope to bring more attention and support to threatened species and those working to protect them.

I've been living on a motorcycle for nearly five years now, on different bikes on different continents. Motorcycles have been a conduit for me to reach the furthest-flung conservation and research sites. Also, being a woman alone on a motorcycle seems to be a compelling way to talk about conservation to those who otherwise might not listen.

A collaboration with Indian, the oldest motorcycle manufacturer in the Americas, sent me to Santiago, Chile, to pick up a 2019 Scout Sixty. After a few modifications to make the bike more off-road friendly, my first stop was the Centro de Rehabilitación de Aves Rapaces (CRAR), a rescue centre for birds of prey in Talagante, just south-west of Santiago's bustling metropolis. In addition to educational outreach, CRAR works in the conservation, rehabilitation and research of raptors in Chile. There to greet me was veterinarian Jürgen Rottman, a respected ornithologist and conservationist. In the early 1970s, as a budding naturalist, Rottman outlined the first list of animals in danger of extinction in the country and disseminated this knowledge to the public in newspapers and on television.

In addition to ongoing conservation work, he now rescues, rehabilitates and releases raptors back into the wild. At the time of my visit there were 25 Andean condors (*Vultur gryphus*) being cared for,

most of them set for future release. The causes of arrival at the centre are diverse, the most common being hunting wounds, theft from nests, collision damage and poisoning. The Andean condors at the centre were the lucky ones, as toxic agricultural poisons such as carbofuran are often used, illegally, to combat predators. When these carcasses are scavenged upon by condors, more deaths ensue.

Last year outside Mendoza, Argentina, 34 Andean condors were found dead next to the corpse of a puma, all due to carbofuran. Such tragedy is as heartbreaking as it is needless. Further education outreach and enforcement are needed, but carbofuran is extremely inexpensive and regulating such a vast, rugged landscape is difficult. Rottman considers himself an optimistic conservationist, believing that there is a solution for almost everything. Thanks to the work by CRAR, some of Chile's condors, hawks, caracaras and owls have a better chance of survival.

OTTERS AND ARMADILLOS

Riding from the foothills of the Andes to the frigid waters of the Pacific, my next destination is the rocky coastal habitat of the endangered marine otter (*Lontra felina*), called chungungo in South America. These otters are the smallest in their genus and are extant within Peru, Chile and Argentina, although their severely fragmented populations are in decline.

Out of the small beach town of Maitencillo the organisation Chinchimén is the first to rehabilitate and release orphaned marine otters back into the wild in Chile. Their most recent rescue arrived dehydrated and suffering from hypothermia and pneumonia. After two months of intensive care the young otter began to flourish and work began to acclimatise her to her natural habitat. Without a proper facility, this entails a volunteer carrying the otter in a crate down a series of steps to the rocky beach daily, letting her swim, play and hunt until she is ready to come back to the crate, before being carried back up the many flights of stairs. Rehabilitating a single otter takes an incredible amount of time and dedication – baby otters learn from their mothers, so without them the learning curve is much slower (up to 18 months).

The estimated population of around 1,400 makes the Andean cat the most threatened and least-known feline in the Americas

Marine otters rely on aquatic habitats for foraging, yet the distribution of the species is limited where people and domestic dogs use the terrestrial habitats they need for shelter – roaming dogs are a huge threat to marine otters, and many people in the fishing industry see otters as competition for resources and kill them.

In the summer months Chinchimén sets up aquariums on the beach for the public to learn about the small animals that live in the coastal waters. When it is time to let the urchins, crabs, invertebrates and other collected creatures go, the children help release them back into the wild. The volunteers of Chinchimén have noticed a change in some of the children – they have started to act as guardians, passing on knowledge of the animals and how to keep them safe. This amazing group of volunteers is not only dedicated to helping endangered marine otters, but also raising awareness, educating the public and increasing empathy among children.

Travelling north, through the Atacama Desert and some of the driest landscapes on the planet, delirious from desert heat and wind, and hypnotised by reflective objects sparkling in the distance, my moto and I reach the Tarapacá region of northern Chile, the landscape of the Andean hairy armadillo (*Chaetophractus vellerosus*).

The armadillos of the high Andean plateau, or Puna, are sacred to the indigenous Aymara

Above left: A young Lao girl identifies the endangered red-shanked douc langur during a wildlife awareness game

Above right: A rescued one-eyed crested caracara in Chile named Pirata

Below: An Andean night monkey kept illegally as a pet in Peru, rescued and relocated by the NPC

population. They adore them and consider these banded, hairy creatures a sign of good luck. Overexploited for traditional purposes, the armadillos are turned into guitars, rattles and other trinkets. Loved to death, they are captured and suffocated or starved so that no marring occurs to their bodies and faces. Additionally, armadillos are used in folk medicine. After being rubbed over a person's body to absorb bad energy and disease, the armadillos are killed.

A study published in 2015 on the taxonomy of armadillos, analysing skull shape and genetics, changed the species designation of Andean hairy armadillos from *C. nationi* to *C. vellerosus*. This moved them from vulnerable on the IUCN Red List to that of least concern. Despite this the Puna armadillo is still considered endangered within Bolivia, Peru, Chile and Argentina. With little enforcement of laws regarding the protection of armadillos in Bolivia, these Xenarthrans need all the recognition and help they can get.

Dead armadillos are sold openly in markets on the border (even in front of immigration offices), where armadillos are being illegally trafficked into Bolivia from Peru and Chile. A campaign by the Wildlife Conservation Society illustrates the idea that 'if you buy, you are an accomplice', showing a tourist purchasing a charango, a Bolivian guitar made from the carapace of an armadillo.

Fortunately, these armadillos are now gaining the attention they need to survive thanks to the NGO Armadillos de Chile. Rominna Pasuiti, a young Chilean veterinarian and conservationist with a deep love for Xenarthrans, discovered there was almost nothing published about the armadillos found in her country. After three years of cultivating awareness, delivering education programmes in the areas where armadillos have become scarce and contributing to the scientific knowledge of the species in Chile, Pasuiti and volunteers are helping turn the tide for the survival of the Andean hairy armadillo.

Above: An education and outreach programme in a remote village on the border of Laos and Vietnam

Below: Kaz with another heritage bike in Colombia

CAT PROTECTION

Riding along the edges of volcanoes through the rugged Andes mountains on a motorcycle is an incredible adventure, with many passes above 4,000m. How impressive to know that this same extreme habitat is home to the endangered Andean cat (*Leopardus jacobita*), the most adorable predator you've never seen.

The Andean cat is a small, wild feline native to the high Andes. The estimated population of around 1,400 makes them the most threatened and least-known cat in the Americas, found only in the rugged heights of Argentina, Bolivia, Chile and Peru.

The primary prey for the Andean cat is the mountain viscacha. It is believed that mountain chinchillas were once their most important prey species, but this shifted once the chinchillas became locally extinct and hunted to the brink of extinction for their fur in most of their range.

The Alianza Gato Andino (Andean Cat Alliance) is a group of volunteers working to contribute to the knowledge and conservation of the Andean cat and its habitat through innovative strategies in research,

conservation, community participation and support in the management of wild areas.

These volunteers dedicate much of their free time to the protection of this mountain cat, despite the fact that they will most likely never see one in their lifetime.

While studying these felids, the Andean Cat Alliance has used camera traps to record footage of them, with stunning imagery and the charismatic *Leopardus jacobita* gracing the scene. Through its research in all range countries of the Andean cat, information about this extremely rare and little-known species is increasing. Additionally, conservation management, education, and local community engagement in conservation are key components of the Alliance's work.

One innovative approach has been to distribute shepherding dogs to ranchers in order to protect their livestock and prevent retaliation hunting.

Riding into the mountains of Peru, from the high Andes down into the Amazon basin, my next mission was meeting with the charity Neotropical Primate Conservation (NPC).

The road, much of it traversing the edge of the jungle, was challenging. This particular area on the Huallaga River is known as the 'door of Amazonia' and it was only in 2015 that a state of emergency was lifted from its upper river valley after 30 years. The valley was notorious as one of the most productive coca regions in the world. Drug trafficking conflict, and the guns that go along with it, are still not uncommon in this area.

At one point I was stopped by people with rifles. They clearly were not police, nor military, but instead wore all black with tactical vests. They wanted money in exchange for 'protecting' the road, but weren't asking for much – one sol, the equivalent of 25p.

PROBLEM PETS

When I arrived to meet Sam Shanee, founder of NPC, the team were treating an endangered Andean night monkey (*Aotus miconax*), which had been illegally kept on a tether as a pet.

Andean night monkeys (or owl monkeys) are endemic to a small area in Peru. Being nocturnal and able to survive in fragmented forests near houses and villages, they are easy to find and catch, but they are not particularly easy to look after. Most people keeping them will only feed them scraps and fruit. Without their mixed diet of fruit, insects, leaves and buds, they eventually get sick and die.

The volunteers of Chinchimén have noticed a change in some of the children – they have started to act as guardians, passing on knowledge of the animals and how to keep them safe

Sadly, this particular monkey had been kept as a pet for so long that it couldn't be relocated and released. Instead it was taken to a zoo in Lima where another Andean night monkey currently resides.

The illegal trade in wild animals for pets is a global conservation and animal-welfare concern. As if habitat loss and environmental degradation were not enough of a threat, wildlife also have a price on their heads.

Wild animals for sale by the roadside are a common sight in South America, where trading and the practice of keeping them as pets has been around for a long time. Many people purchase these wild animals out of pity, believing they can offer them a better life. However, their money is perpetuating the trade and usually the buyer has no idea how to care for the animal appropriately, especially as it transitions into adulthood.

Many people ask me if I'm afraid to live my life this way – alone on the road on a motorcycle seeking the stories of wildlife protection. The truth is, before I started doing this I felt tremendous despair for the state of our planet and with my own inaction. I feel far more fear of doing nothing, of pretending like the atrocities happening to our planet and its creatures don't affect me.

We have massive obstacles to overcome in the protection of our planet and its inhabitants, but one thing is clear – anything helps. Whether it's conserving an entire species, a population, an ecosystem, or an individual animal or small plot of land, we can all do our best to help biodiversity where we are and support those who are doing so elsewhere.

You can follow Janelle Kaz's journey on Instagram **@motogypsy** or on her website **www.motogypsy.org**
To find links to the organisations Janelle visited see the online version of this story at: **thebiologist.rsb.org.uk/biologist**

Top: Baby Chungita, an orphaned, endangered marine otter that later became the first otter to be rehabilitated and released into the wild in Chile

Left: Andean hairy armadillo, considered sacred by the Aymara people

Janelle Kaz is a biologist, journalist and environmental advocate who has spent the last five years travelling across three continents. Her mission is to document and assist groups taking action to protect ecosystems and the people who depend on them.

A day in the life

Emma Beaton MRSB on searching for marine invertebrates on the Falkland Islands' coasts

MY WORK INVOLVES...

Examining marine invertebrates that inhabit the rocky shores of the Falklands and the factors influencing the structure of these communities. I am a PhD student at the University of Aberdeen and survey shores around the islands to determine how the invertebrate communities change within the intertidal zone and across different islands across the Falklands. I also have two sites that I visit every three months to determine how the faunal communities change seasonally.

ON A TYPICAL DAY...

My fieldwork is completely dependent on the tides, so the times of my surveys can vary immensely. The Falklands have a small tidal range, so I try to be in the field during spring tides when the water is at its lowest.

I need to fly out to one of my seasonal sites using the Falkland Islands Government Air Service, which comes with the bonus of a bit of whale and dolphin spotting as we cross the Falkland Sound.

I carry out transect-quadrat surveys with the help of a volunteer and collect invertebrates from under boulders within each quadrat. I then take the collections back to the house in the settlement to identify and count the invertebrates. I set up a 'lab' in the dining room for the critter counts, which can take several hours.

Emma Beaton collects invertebrate samples from under boulders

Dr Marina Costa

I WORK WITH...

The South Atlantic Environmental Research Institute (SAERI) when I'm in the Falklands. SAERI is a fantastic hub for research across the UK overseas territories in the South Atlantic.

Our research projects are very diverse, from studying intertidal ecology to assessing natural capital. I also work with volunteers from the local community, who take a real interest in the research being undertaken on the Falkland Islands and are keen to help out wherever they can.

RIGHT NOW I AM...

Back at the University of Aberdeen analysing the quadrat photos I collected during my fieldwork, counting the invertebrates on the surface of the boulders and assessing the substrate. I am also working on another chapter of my PhD using DNA barcoding techniques to identify cryptic seaweed species of the Falklands.

Saunders Island, the Falklands

The career ladder

Julie Roberts CBiol FRSB says 'you don't need a first-class degree to have an amazing career'

AT THE MOMENT...

I run my own pharmaceutical consultancy. I am usually based at a pharmaceutical manufacturing site, helping them get ready for a regulatory inspection or remediate after a poor inspection, or providing support on new projects. I spend most of my time overseas, usually in India, South Korea or America, and so far I have been lucky enough to travel to 52 countries, including some high-risk places such as Syria and North Korea.

I STUDIED...

Environmental sciences, specialising in microbiology. Ten years into my career I went on to do a master's in pharmaceutical sciences at Brighton University. Having always managed to obtain average grades at school and only a 2:2 in my degree, with hard work I finally succeeded, obtaining a distinction.

MY FIRST FULL-TIME JOB INVOLVED...

Testing milk at a Liverpool dairy. From there I progressed into the pharmaceutical industry as a microbiologist testing water, the production environment and products. As a site microbiologist I saw all parts of the business when investigating problems.

I could be on the roof sampling puddles, in the basement dismantling pipework that had been in place for 40 years and even swabbing noses looking for *Staphylococcus aureus*. I moved into a technical role advising on the design of cleanrooms, high-quality water systems and other aspects of quality control.

THE BEST THING ABOUT MY CURRENT JOB...

Is that I get to travel the world, experience different cultures and help people bring life-saving and life-changing medicine to market.

THE WORST THING IS...

The misapprehension that the pharmaceutical industry is the big bad wolf. Working in the industry for almost 30 years I have seen numerous products fail after years of costly research and clinical trials. I know how expensive and time consuming it is to bring safe and efficacious products to market.

MY KEY PIECE OF ADVICE WOULD BE...

I wish I had applied myself better at school and during my first degree, although in all honesty I have had an amazing career, which is still giving me great pleasure 30 years on. I'm proof that you don't need to be an A* student with a first-class degree to have an amazing career.

My Society and me

RSB honorary secretary Professor Richard Reece FRSB on accrediting degrees

I have been at The University of Manchester since 1995 – my current role is associate vice-president with responsibility for teaching, learning and students across the institution.

I was invited to join the Society's predecessor, the Institute of Biology, in 2001. I managed to studiously ignore this invitation until 2009 when, following the formation of the Society of Biology, I was elected as a Fellow.

By that time I had also started working with the Society on the underlying principles that would go on to form the basis for the

Professor Reece has worked at The University of Manchester since 1995

accreditation of UK biology degrees. After these principles were formulated and more widely accepted by the Society's Council and the membership, the task of showing that accreditation could work began. I chaired the majority of the pilot accreditation processes that oversaw the principles being put into practice.

I continue to work with the excellent accreditation team to this day as the RSB's accreditation system expands internationally.

I was first elected to Council in 2013 and was appointed as honorary secretary in 2016. This latter role is hugely fulfilling and affords me the opportunity to be at the very heart of an exciting and vibrant organisation.

The unified 'voice of biology' has, in my view, been enormously beneficial to the sector and will continue to be so.

Opportunities, awards and events

A round-up of upcoming RSB activities for members

FUNDING

Student and early-career members of the RSB can now apply for a **travel grant** of £500 to support future overseas travel in connection with biological study, teaching or research. The deadline for applications is 1st March 2020.

Further details on eligibility and how to apply can be found at **www.rsb.org.uk/travelgrants**

CAREERS

The Society is now offering an **Industry Skills Certificate** designed to support early-career biologists with their continuing professional development, particularly to help those in academia train in areas relevant to industry. Participants must undertake a minimum of five courses within a 12-month period, including one compulsory course. For more information contact **training@rsb.org.uk**.

COMPETITIONS AND AWARDS

Registration is now open for the **British Biology Olympiad 2020** (held from 31st January to 7th February) and the **Biology Challenge 2020** (from 10th to 31st March).

Join the HUBS workshop for newcomers to lecturing and teaching

Visit **www.rsb.org.uk/competitions** or email **competitions@rsb.org.uk** for more information.

The RSB's **School Biology Teacher of the Year** is open to all teachers who are working with students aged 11 to 18, teaching pre-university-level biology programmes of study and currently employed in a UK-based school or college. Nominations for the 2019 award close on 20th December 2019. Visit **bit.ly/RSB_STY2020** for more information on previous winners and how to apply or nominate a teacher.

The €20,000 **Eppendorf Award for Young European Investigators** is open until 15th January. Granted annually, the award recognises outstanding contributions to biomedical research through molecular biology, including novel analytical concepts. See **www.eppendorf.com** for more details.

COURSES

The Society and Heads of University Biosciences (HUBS) group is hosting a **workshop for newcomers and relative newcomers to a university and teaching career**. The workshop, free for attendees from HUBS member universities, will also be of interest to researchers, postgraduates, hourly paid staff and visiting lecturers.

It will be held on 10th January at the JBS Haldane Student Hub, University College London, 09:30–16:15. For details and to book a place visit **www.rsb.org.uk/events**

Education and training

The Society's programme of courses and workshops

COPYRIGHT AWARENESS FOR RESEARCHERS

22 January, 09:00–17:00
RSB, 1 Naoroji Street, London WC1X 0GB

This course is for anyone involved in research, from PhD students to laboratory heads, and teaches the basics of copyright law. From creating your own intellectual property to making use of others', this programme will help introduce researchers to the key laws and rights associated with copyright, case studies and how to manage risks.

21 CPD points
From £100 + VAT

QUALITY MANAGEMENT

31 January, 09:30–16:30
RSB, 1 Naoroji Street, London WC1X 0GB

A day designed to develop skills and knowledge in quality management, taught over four sessions, covering an introduction to quality management, governance, risk management and compliance. It is designed for anyone who is new to the workplace, aspires to be a manager or is new to a management role and wishes to develop their quality management skills and knowledge in quality management.

18 CPD points
From £120 + VAT

AN INTRODUCTION TO PHARMACOKINETICS IN DRUG DEVELOPMENT

6 February, 09:30–17:30
RSB, 1 Naoroji Street, London WC1X 0GB

This course will provide participants with an overview of how pharmacokinetics (PK) information is generated and used within drug development. Common PK terms will be explained, and the different methods used to analyse PK and pharmacodynamic data will be introduced. Throughout the course participants will have the opportunity to apply the knowledge gained through taking part in a selection of quizzes and case history exercises. This course does not require specialist knowledge and is intended for all professionals who have an interest in how PK is used within drug development.

21 CPD points
From £120 + VAT

MEDIA COMMUNICATION TRAINING

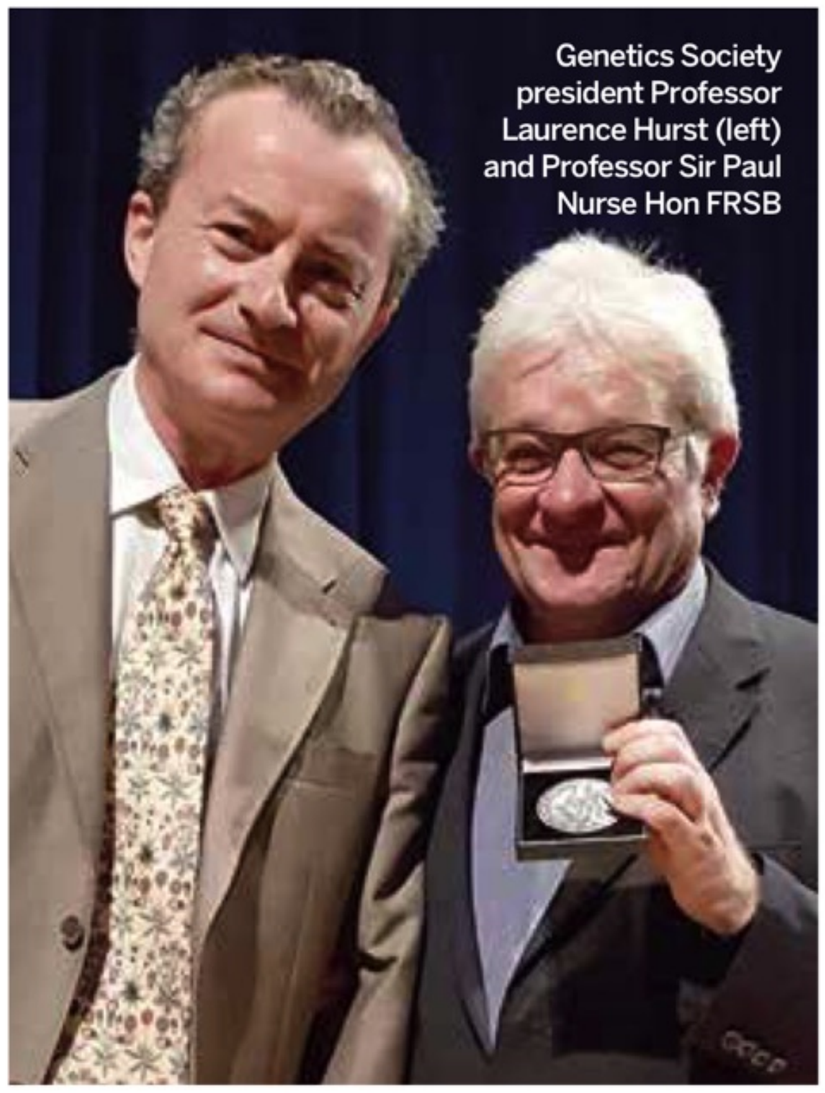
10 March, 10:00–16:00
RSB, 1 Naoroji Street, London WC1X 0GB

This one-day course provides participants with an introduction to the media. It covers radio/podcasts, print/online and social media, with the aim of demystifying the journalism process. Delegates will come to understand what journalists require for different media, as well as how to give a good radio interview and provide quotes.

This training course is for anyone who would like to gain skills in media and how to communicate through different platforms.

15 CPD points
From £120 + VAT

The John Innes Centre garden, featuring a double helix sculpture, won silver at the Chelsea Flower Show



Genetics Society president Professor Laurence Hurst (left) and Professor Sir Paul Nurse Hon FRSB

100 years of genetics

The Genetics Society has spent 2019 celebrating its centenary

The Genetics Society was founded in 1919 by William Bateson and Edith Rebecca Saunders as the world's first society devoted to the study of the mechanisms of inheritance. One hundred years later, as a learned society we aim to support and promote the research, teaching and application of genetics. Our membership includes more than 2,000 of the UK's active professional geneticists, including teachers, researchers and students.

We organise one annual scientific meeting, award various medals and prizes to researchers in distinct stages of their careers, and offer our members a variety of grants to support them to attend meetings and courses.

To mark our centenary this year we developed a varied programme of events dedicated to honour our history and the field of genetics. From launching our new podcast – 'Genetics Unzipped' with Kat Arney – taking genetics to Einstein's Garden at the Green Man Festival to sponsoring the Royal Institution's Christmas Lectures we had a year full of centenary celebrations.

Back in March we teamed up with the Mendelianum, a museum in the Czech Republic dedicated to the work of "the father of genetics", Gregor Mendel, and hosted the International Mendel Day with an afternoon of talks dedicated to Mendel and women in genetics, followed by an evening public talk by our Mendel Medal awardee, Mary-Claire King.

Back in the 1900s William Bateson was introduced to the work of Gregor Mendel and presented his work during a Royal Horticultural Society (RHS) lecture. To commemorate our ties with the RHS we designed a garden for the Discovery Zone of the Chelsea Flower Show. The focal point of our exhibit 'A Flowering of Genetics' was a hybrid zone of snapdragons and a DNA double helix sculpture made by the John Innes Centre, which represented Mendel's work with peas and pyloric snapdragons, showcasing the story of genetics and why its study is fundamental to our understanding of health and disease. The exhibit was awarded a silver medal.

To celebrate 100 years to the day since the first meeting of the then-named Genetical Society, a birthday get-together of past presidents, medal winners and committee members was held at the John Innes Centre on 25th June 2019. Two blue plaques (dedicated to Bateson and Saunders) were unveiled by ex-Society president Sir Paul Nurse and will be erected in Cambridge next year.

Genetics Society president Laurence Hurst presented the Centenary Medal to Sir Paul, who then gave a talk about his work with yeast. A birthday party was later held at The Assembly House in Norwich.

It has been quite a journey, and we couldn't have achieved such a successful year without the hard work of the centenary committee, our members and all our volunteers. We are very thankful for all their support and hard work. All these events have helped to not only celebrate our centenary, but also to raise our profile and engage with our membership and the public.

We are looking forward to developing new projects that will build the legacy arising from our centenary activities.

REVIEWS

The best books for biologists, nature lovers and their families

OPEN ECOSYSTEMS: ECOLOGY AND EVOLUTION BEYOND THE FOREST EDGE

William J Bond

Oxford University Press, £55.00

The non-forested open ecosystem is the focus of William Bond's book, but not because such ecosystems comprise a greater percentage of available land. Rather, the fact that many non-forested land areas could be forested is the intriguing point. He asks why forests are not present when there is sufficient rain, the soils are suitable and temperature amenable.

Shrubs, grasses and open woodland may thrive, but dense woodland is not present. As far as Bond is concerned this situation goes against the assumption that climate determines the major vegetation type. The example given is the Cape fynbos, the dominant vegetation type around Cape Town, South Africa. Chapter one explores this anomaly, concluding that the fynbos has no extensive dense woodland because of the natural fire events that destroy larger trees, but stimulate growth of the unique ground flora. Subsequently, the fynbos becomes dominant.

Over eight further chapters, the author covers the nature of open ecosystems, their origins, soils, herbivory and human interference in preventing and stopping natural fires. Discussing the nature of open ecosystems, three global 'traits' of vegetation are explored: black, brown and green, referring to what consumes the vegetation. Black world traits are those in which fire is the consumer, brown refers to survivors of herbivory while green is for shade-tolerant plants.

Yet trees do survive through all this because of adaptations. Take for instance 'underground trees', or geoxylic suffrutices, that sprout after fire on the surface. These are the product of extensive buried branches from which stems develop to produce a shrub growth form rather than a full-blown tree.

Bond provides a fascinating account of a poorly considered area of ecology. He presents a sound argument to the consideration of non-forested areas being just as important as – and sometime more important than – the favoured dense forest as the epitome of ecological health. Packed with references, images, diagrams and colour plates, *Open Ecosystems* is a thorough, exhaustive textbook for the ecology and conservation professional.

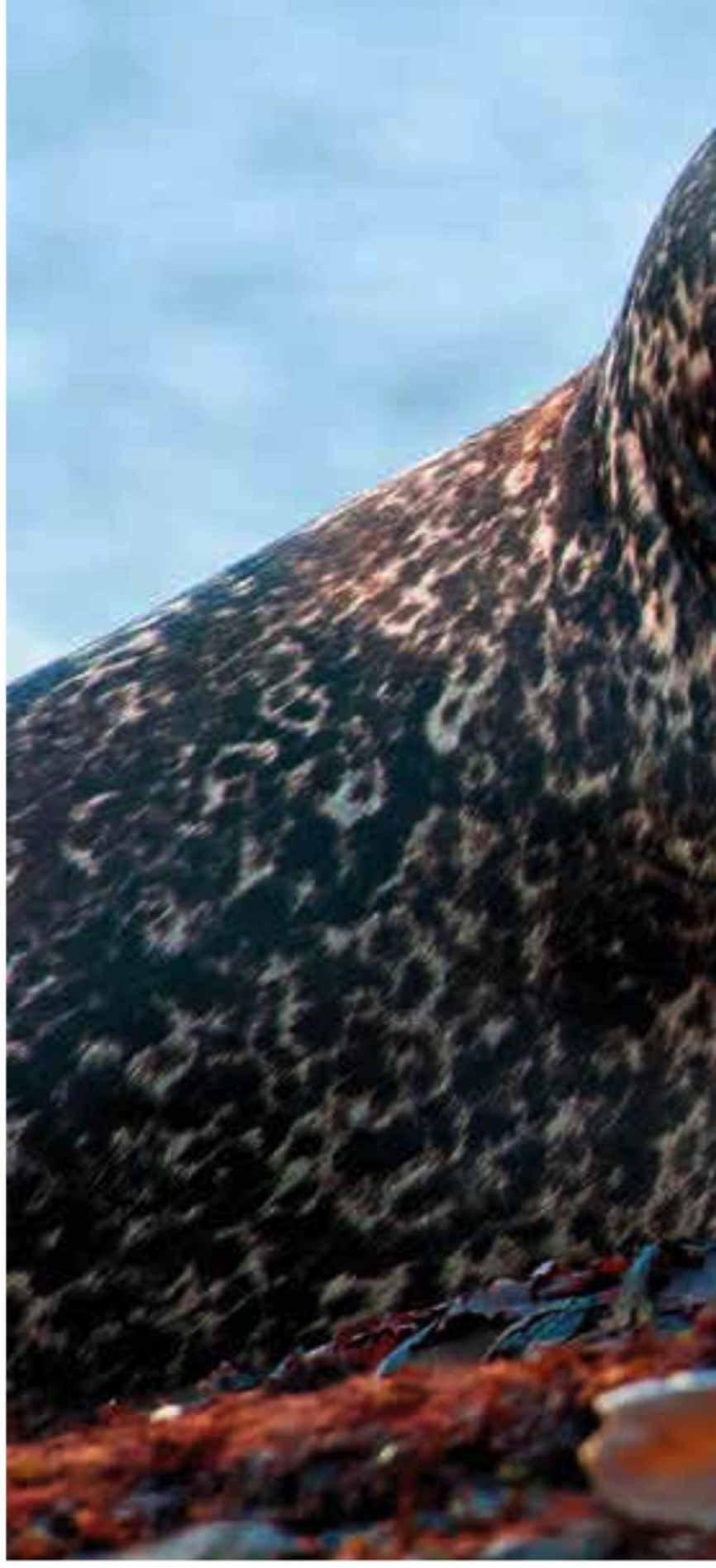
Pat Sang MRSB

AN EDITOR'S GUIDE TO WRITING AND PUBLISHING SCIENCE

Michael Hochberg

Oxford University Press, £27.50

Writing for peer-reviewed publications is an integral part of the job for many biologists, and communicating clearly and concisely the outcomes of research is important. However, all too often papers are rejected for poor writing as much as for the quality of the reported research. The nuanced style and coded structure of scientific writing is a complex craft and it can take a long apprenticeship to learn, typically in parallel with the pathway from postgraduate student to independent investigator. In this context the author presents an invaluable compendium of insider's tips and pitfalls to avoid in preparing a paper to submit to a journal.



As editor-in-chief of *Ecology Letters* for a decade, Hochberg has read thousands of manuscripts so is in a position of authority to discuss how and how not to write scientific research for peer-reviewed publication. This readily accessible text covers all the steps, from selecting an appropriate journal to dealing with the revision and resubmission process.

The stages of manuscript writing are dissected, providing detailed advice on

'Fynbos' is a belt of natural shrubland or heathland found around Cape Town, South Africa

Europe's Sea Mammals aids identification of pinnipeds such as harbour seals (*Phoca vitulina*) and cetaceans

completing each standard paper section. The peer-review process is demystified, including how referees are selected and common reasons for rejection. Strategies for rebutting a reviewer's critical appraisal and what to do if your paper is rejected are perceptive and emboldening. The emerging challenges of archiving and sharing data, article-processing charges and the influence of citation metrics are each considered.

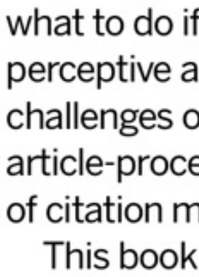
This book is highly recommended to postgraduate students, postdoctoral researchers and early career academics.

Professor Andrew Taylor-Robinson CBiol FRSB

EUROPE'S SEA MAMMALS: INCLUDING THE AZORES, MADEIRA, THE CANARY ISLANDS AND CAPE VERDE

Robert Still, Hugh Harrop, Tim Denton and Luis Dias

Princeton University Press, £20.00



Trying to identify a sea mammal can be tricky because most move so fast all you get is a glimpse of a tail, fin, flipper or head, and they are usually a long way from shore.

Robert Still and his co-authors have found a solution: produce a little book full of images of fins, tails (flukes) and blow forms for the Cetacea, supported by diagrams, written descriptions and tips on where and how to find them.

After the single-page descriptions of each species comes a large section of detailed information about the cetaceans and pinnipeds, with notes on communication, breeding and conservation. This is followed by rescue information, species' classification and then legislation for sea mammal watchers to refer to. A thorough reference list is found on pages 196–201 and the final pages give us non-English names of the cetaceans covering French to Spanish naming.

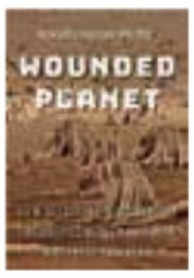
Europe's Sea Mammals is one in a series of 'WildGuides' titles published by Princeton University Press and the care and detail put into this title is difficult to surpass.

Pat Sang MRSB

WOUNDED PLANET: HOW DECLINING BIODIVERSITY ENDANGERS HEALTH AND HOW BIOETHICS CAN HELP

Henk A M J ten Have

Johns Hopkins Press, £48.00



The relevance of the environment to health is clearest in situations such as natural disasters and famines, but the connection holds more widely. Everyone's health is influenced by the quality of their natural environment, nutrition, education and hygiene; our health is determined more by the conditions of everyday life than by medical treatment and healthcare services.

Mainstream bioethics often addresses the care and autonomy of individual patients without considering the social and environmental conditions on which their health depends. *Wounded Planet* instead argues that we need to bring medical ethics and environmental ethics together to create global bioethics, which covers medical, social and environmental concerns. Biodiversity and human health should be considered together, alongside the wellbeing of future generations.

Wounded Planet reviews the key topics that global bioethics must address, including health, food and water. In many cases the description is overwhelmingly about social structure rather than biodiversity. Such discussions are fundamental but, although the book's tagline starts 'how declining biodiversity endangers health', biodiversity was at times peripheral to discussions. Instead, the book is a call to reassess neoliberal values and challenge the promise of markets and technology to fix problems. Ten Have highlights the need to tackle problems at their root cause, and to ask what kind of world we want to live in and leave for future generations.

Superlative looks at the biggest, fastest, noisiest and tallest

The important dilemmas highlighted by *Wounded Planet* include whether we should drain swamps or use pesticides to reduce vectors of disease even if these measures may reduce biodiversity, with potential longer-term health impacts. In order to answer questions where biodiversity conflicts with human health, ten Have touches on the topic of whether nature has intrinsic value. However, this is not explored sufficiently to shed light on how different perspectives would lead to particular answers.

Dr Rebecca Nesbit

SUPERLATIVE: THE BIOLOGY OF EXTREMES

Matthew D LaPlante

BenBella Books, £17.99

Did you know that the African elephant, the largest land animal, could help find a cure for cancer or that the Goliath frog could shed light on the science of aging? The giraffe on the other hand has advanced the question of speciation with the discovery that it is not one species but several, all thanks to DNA analyses that showed extensive genetic diversity between populations.

At the heart of these stories are organisms at the extremes of biology. The biggest, the tallest, the fastest, the oldest and the noisiest – and thus the most superlative results of evolution.

LaPlante writes his book as a personal account of his research into the extremes of living things, an interest first piqued by a meeting with a baby elephant in a zoo. The non-formal style is brilliant to read, but there is a scientific depth that shows a great understanding of the fragility and importance of all living things.

Superlative comprises eight chapters covering the greatest and the tallest, the smallest and the smartest – which, as far as the author is concerned, is not human. Each chapter has sections not listed on the contents pages and this would have been useful as some sections are particularly fascinating – for example, the one on the hog-nosed bat, aka the bumblebee bat and the world's smallest mammal. However, each chapter is expanded in a notes section toward the end of the book and there is a comprehensive index.

Superlative is a refreshing and accessible work, full of fascinating content and at a price that surely does not reflect the effort of creating it.

Pat Sang MRSB

SIX LEGS WALKING: NOTES FROM AN ENTOMOLOGICAL LIFE

Elizabeth Bernays

Raised Voice Press, £12.99

Some people are born entomologists,and some have entomology thrust upon them. Elizabeth Bernays belongs very much to the former category. In this series of essays, many of which have been published before but which together form a seamless whole, she describes her life from a "backward" child to becoming a renowned entomologist who, with her lifelong partner,

Reg Chapman (of *The Insects: Structure and Function* fame), has travelled the world undertaking both applied and pure research, mainly into insect feeding (what are the advantages for a grasshopper to be a specialist or generalist feeder? What are the factors that determine herbivore population dynamics?).

Her insights into all things entomological form a backdrop to stories of the steamy Anti-Locust Research Centre in the swinging sixties (who would have known!) to Nigeria, India and, most recently, more serene reflections from the deserts of the US.

Although *Six Legs Walking* is not primarily a scientific primer, it is full of ideas that may stimulate scientists in other areas – I hope to start looking at host fidelity in mosquitoes in greater depth as a result of her book.

Thanks to her writing 'the cold skeleton of reason acquires living, rosy flesh and … science flourishes', to quote Julien Offray de La Mettrie. It is very easy to read and scores very highly on the feel-good factor. Highly recommended.

Derek Charlwood

THE GARDEN JUNGLE: OR GARDENING TO SAVE THE PLANET

Dave Goulson

Penguin, £16.99

In *The Garden Jungle*, Professor Dave Goulson has written what is perhaps his most personal book to date and outlines his perspective on how we can garden for wildlife.

Within this book Goulson describes various bugs and beasties that scuttle around our gardens, regularly unnoticed, and suggests how and why we should care about these animals.

Bumblebees and other species of bee (of which Goulson is an enormous fan) are well known for their importance in pollination, but he also highlights the major roles of earthworms, hoverflies and even earwigs, among other animals, in maintaining our gardens and in agriculture.

This book is not meant as a gardening guide (although there are useful tips) – it is more of a thought-provoking read about how we produce food and our relationship with our gardens.

Goulson's colourful anecdotes make this book an easy read but, while he is optimistic and cheerful throughout, his frustration at large-scale food production and agrochemical companies is also clear.

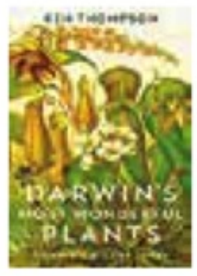
The Garden Jungle will inspire people who have a garden to tend it for wildlife, and will make those who don't have a garden want one more than ever!

Dr Harry Siviter

DARWIN'S MOST WONDERFUL PLANTS: DARWIN'S BOTANY TODAY

Ken Thompson

Profile Books, £8.99



Charles Darwin is rightly most famous for his work *On the Origin of Species*, but spent the greater part of his time in detailed experimentation, much of it looking at weird and wonderful plants. Insights from this work informed his great theory, but also answered questions that nobody else realised were even questions.

In *Darwin's Most Wonderful Plants* Ken Thompson delves into the various strands of botanical research that occupied Darwin, including the movement, carnivory and sex life of plants. In each of these main chapters Darwin's research is described, including with concise quotes and illustrated with his original diagrams, placed in context and brought up to date with brief outlines of current research on the topic.

The writing style is both concise and informative, leavened with a sardonic humour throughout. The science is discussed clearly without getting bogged down in details or deviating from the main argument, and the technical information is carefully explained.

Ken Thompson's *Darwin's Most Wonderful Plants* is an excellent read for amateurs and experts, and casts a delightful light on a fascinating man and an intriguing subject.

Ellis O'Neill

All creatures great and small – even earwigs – are welcome in *The Garden Jungle*

BRANCHES

Upcoming events near you and regional news

Event calendar December 2019 onwards

Professor Sue Black OBE Hon FRSB will join the Scotland branch to discuss science and criminal justice

WEST MIDLANDS

CHRISTMAS SOCIAL, SEASONAL TALKS AND FESTIVE QUIZ

Tuesday 10 December 2019, 19:00–21:00

Join the West Midlands branch for a festive series of short talks followed by refreshments and seasonal treats, a quiz and social. Open to RSB members (£3) who are welcome to bring one guest.

Room SCT009, Seacole Building, Westbourne Road, City South Campus, Birmingham City University, Edgbaston, Birmingham B15 3TN

THAMES VALLEY

YOUNG BIOLOGISTS FORUM 2020

Thursday 30 January 2020, 09:00–16:00

Discover the wealth of biological careers and research opportunities at the Young Biologists Forum. Hosted by the RSB and the University of Reading, there will be 10-minute talks from various biology-based industries on their current research and graduate employment schemes, plus networking opportunities with professional biologists. Free and open to all.

AMS Foyer, AMS Building, University of Reading, Whiteknights Campus, Reading, Berkshire RG6 6AH

YORKSHIRE

FRONTIERS OF SCIENCES V

Saturday 14 March 2020, 10:00–15:00

This year's Frontiers of Sciences meeting is taking place in association with the RSB, the Network of Researchers on the Chemical Evolution of Life, the Royal Society of Chemistry and the Astrobiology Society of Britain. Four speakers will explore topics around the origin of life.

The event is free to attend but advance booking is essential.

KPMG LLP, 1 Sovereign Square, Leeds LS1 4DA

SCOTLAND

DAME SUE BLACK: SCIENCE AND CRIMINAL JUSTICE

Saturday 23 May 2020, 10:30–12:30

As part of the Royal Society of Biology's 10th anniversary, the Scotland branch is hosting a talk by Professor Dame Sue Black titled 'Is your hand unique? How can science assist the criminal justice system?' Dame Sue will reflect on her current research areas and consider research directions for the next 10 years.

Sir Ian Wood Building, Robert Gordon University, Garthdee Road, Aberdeen AB10 7GJ

Gary Doak/Alamy Stock Photo

FOR DETAILS www.rsb.org.uk/events

Event reports

DEVON AND CORNWALL

MARINE TURTLES AND CLIMATE CHANGE

9 October 2019

This public lecture, organised by Dr Rich Boden FRSB and his colleagues at the University of Plymouth, attracted almost 300 attendees during Biology Week.

Professor Annette Broderick from the University of Exeter's Cornwall campus at Penryn spoke engagingly about her work with marine turtles over the last 20 years. Her research has been mainly with populations of loggerhead turtles (*Caretta caretta*) and green turtles (*Chelonia mydas*) nesting on Cyprus, but she also presented data from sites on Ascension Island (turtles choose nice beaches).

She introduced us to 'pivotal temperature', sex ratios and egg-laying depths, as well as to the near-impossible task of visual sex determination in turtle hatchlings. Professor Broderick did not shy away from presenting research data in the form of complex graphs, but she explained her team's findings in such a way that the audience could grasp their significance.

As the gender of marine turtle hatchlings is temperature dependent, environmental warming could be expected to have a catastrophic effect on turtle populations. We were presented with modelled data to show what could happen if sea temperature rises by up to 4°C, before Professor Broderick explained several behavioural changes that have been observed, with one example being that egg deposition is now happening earlier in the year than when the team started recording in 1992.

This was not a 'marine turtles are doomed by the action of mankind' talk. This was a balanced account of turtle nesting behaviour and population dynamics based on almost 30 years of field observation, recording and tracking. It was an inspirational talk for all of the early-career biologists who packed the lecture theatre.

Dr Ian Varndell CBiol FRSB

EAST ANGLIA

AGM AND GUIDED WALK OF WANDLEBURY

18 September 2019

The RSB East Anglia branch AGM was followed by a guided walk around key features of Wandlebury, a country park south of Cambridge. This proved to be an interesting mix of history and ecology. It included a description of the original estate


A calming countryside walk with alpacas

and its gardens, photographs of previous inhabitants, the lost gardens, a mention of Godolphin – one of three Arabian stallions that founded the modern thoroughbred racehorse – buried beneath the stable archway, and a description of the Iron Age fort and Roman roads.

The group then walked across rare chalkland fields where key wildflowers were identified and their medicinal properties discussed, including wild parsnip, marjoram and other plants such as agrimony, wild scabious and lady's bedstraw. The latter was used as mattress stuffing and as a treatment for a variety of skin disorders. It was fascinating to witness how dispersal of wildflowers across the chalklands had been achieved due to grazing by a herd of Highland cattle.

Dr Denise V Dear MRSB

BIOLOGY WEEK: WALKING WITH ALPACAS ADVENTURE

Thursday 10 October 2019

The East Anglia branch celebrated Biology Week 2019 in style with a visit to Misty Meadows Alpacas for a walking with alpacas adventure. Karen Hepworth-Lavery set up the company after going on an alpaca walk and falling in love with the animals, with their distinctive personalities and gentle nature. She and her husband were inspired to bring this experience to life for others, buying 12 alpacas and setting up Misty Meadows Alpacas, a relatively small local operation dedicated to the welfare of these creatures.

Members of the East Anglia branch were hugely grateful for the chance to walk with these charming animals in the scenic countryside location of Maxey. Our day started with getting to know how to care for alpacas and a bit more information about them. We discovered that they hum when curious, content, worried, bored, fearful, distressed or cautious.

We then each chose an alpaca and went on a lovely countryside walk, leading our alpaca on a rope – it was like walking a very large, calm, fluffy dog. The walk itself was a great experience and we enjoyed a wonderful hour of rambling with our new woolly friends. Finally, we got to hear a bit more about life with the alpacas and we had the opportunity to feed them their favourite food – carrots – as a reward for our stroll with them.

Our alpaca walking trip was an experience loved by all present. Many of us wanted to take our alpacas home, but rest assured they are still safely at Misty Meadows, where they can be enjoyed by other visitors in future.

Natalie Lamb RSci MRSB

NORTH WALES

VISIT TO NEWBOROUGH FOREST

5 October 2019

North Wales branch members met at Newborough Forest on Anglesey for a walk guided by Graham Williams of Natural Resources Wales (NRW).

The area is part of two Special Areas of Conservation, a National Nature Reserve and a Site of Special Scientific Interest covering 2,303 hectares including shingle beach, sand dunes, salt marsh and dune slacks.

The 700-hectare Corsican pine forest was planted after the Second World War to stabilise the mobile dune system, replenish stocks of pit props after the mining effort during the war and provide employment for men returning from active service. The

whole dune system was more than 70% bare sand before the pine trees were planted and now only 2–3% of the area (> 0.5 hectares) is bare sand. Williams showed us the work that NRW is doing to manage the dunes for conservation.

Newborough Forest is home to red squirrels, so there is local resistance to any tree felling, but agreement was eventually achieved to fell small areas along the coast where the trees were wind damaged.

In one area NRW felled trees and left the roots *in situ*; in another area they extracted the tree roots. They cut artificial 'notches' through the dunes to the sea to allow the longshore wind to erode the sides of the notch to push the sand inland and encourage the growth of marram grass, sand sedge, rest harrow, lyme grass and sea spurge.

Sand lizards and rare beetles are seen in this area, which is replacing the ruderal flora that had established on the stabilised and shaded dunes over the years. These experimental areas will provide the information NRW needs to better manage the reserve to increase its biodiversity.

Not only do the flora and fauna make management of this area complex, but also the geology, hydrology, geomorphology and the impact of climate change.

Dr Rosemary Solbé FRSB

SCOTLAND

BIODIVERSITY IN SCOTLAND

12 October 2019

Dr Liz Lakin FRSB gave a warm welcome and chaired RSB Scotland's Symposium on Biodiversity in Scotland at the University of Glasgow's Kelvin Hall lecture theatre. The three guest speakers – Professor Nigel Willby (University of Stirling), Charles Dundas (the Woodland Trust) and Toby Wilson (RSPB Scotland) – shared their recent work on biodiversity in freshwater, woodland and city environments respectively.

This event was timely, as many attendees had recently received the news that the abundance of species in Scotland is declining at a faster rate than elsewhere in the UK.

The speakers placed their findings in a national and global context via the State of Nature Scotland Report 2019 and WWF's Living Planet Report 2018, presenting attendees with some concerning biodiversity statistics.

However, some good-news stories were also shared, with examples of biologists working alongside land/river managers, policymakers, property developers and the public to improve Scotland's biodiversity. From beaver dams to management of coastal temperate rainforest and citizen science informing building developments, these heartening stories sparked engaging discussions during the panel Q&A.

Dr Jacqueline Nairn FRSB

WESSEX

DAY TRIP TO THE HAWK CONSERVANCY TRUST

30 July 2019

Fortunately, the dreadful weather forecast predicting high winds and heavy rain did not deter the 25 members, plus friends and family, who turned up to the Hawk Conservancy Trust to enjoy a very full and varied day. A highlight was a talk about the

The North Wales branch on the dunes at Newborough Forest

Mark Ashton

Flying a Harris's hawk on the Wessex branch trip to the Hawk Conservancy Trust

National Bird of Prey Hospital where 200 ill, injured or orphaned birds are treated each year. This was followed by a tour of the treatment rooms, nursing bays and rehabilitation wing.

Everyone enjoyed the flying displays, the most impressive of which involved not only owls, eagles and vultures, but also secretary birds and sacred ibis. As well as visiting all of the birds and learning the current threats to their continued existence in the wild, some of us chose to handle a Harris's hawk, providing plenty of photo opportunities.

The Hawk Conservancy Trust was formed in 2002 to take responsibility for bird of prey rehabilitation, conservation and research activities. Today conservation and education work continue on a global scale, so we were particularly fortunate to finish the day with a lecture from Dr Campbell Murn FRSB, head of conservation and research at the trust.

Dr Murn's research specialism is in vulture conservation. Vultures are the most threatened group of birds globally, with 70% of vulture species having poor or very poor conservation status. Dr Murn focused on the significant decline in African vulture populations due to poisoning of elephant carcasses by poachers and secondary poisoning (aimed at top predators) by farmers in retaliation for taking livestock. Habitat loss and climate change are influential factors too.

Conservationists working in this field face many challenges – including funding, equipment provision and the need for accurate data on vulture strongholds, population numbers, genetic profiles and ecosystem health – so effective landscape-scale actions can be implemented.

The group's enjoyment of the day was increased by having a comfortable room at our disposal. This was particularly welcome for those of us with picnic lunches as it meant we were able to dodge the rain and stay relatively dry throughout the day.

Dr Hilary Otter FRSB

WEST MIDLANDS

AN INORDINATE FONDNESS FOR BEETLES

15 August 2019

Members and non-members came from across the West Midlands and further afield to take part in the all-day workshop on beetle identification at Bishops Wood Field Study Centre near Stourport-on-Severn in Worcestershire. The event was organised with the Field Studies Council's BioLinks project, which subsidised courses for those interested in learning monitoring or recording skills. Katy Potts (@KatyPottsEnto) from the Natural History Museum (NHM) in London ran the sessions with support from Holly Dillon from BioLinks.

We used excellent binocular microscopes provided by the centre and trays of Coleopteran specimens from the NHM. Some of the specimens were more than 100 years old and had to be handled carefully.

While the focus of the day was on enabling identification of UK beetles to family level, some of the more exotic species proved popular, including the giraffe-necked beetles. After an illustrated introduction to the main families, there was time to practise and build up confidence in identification – in some cases, identifying to genus and species level.

A useful tip to distinguish beetles from true bugs is to look at how the wing cases are folded. Wing cases of true bugs form a Y or an X shape (apart from aphids and scale insects), whereas those of beetles form a T shape.

A sunny day meant that participants enjoyed lunch outside by the pond and took part in a rewarding postprandial beetle hunt. Many different beetles were found, particularly under logs.

Our thanks go to the Field Studies Council's BioLinks project, which aims to bring together those with skills in biological identification and new volunteers to improve the quality of invertebrate species data being submitted to national biodiversity datasets, and to develop individuals as more highly skilled biodiversity volunteers. By the time we left the workshop all of us were certainly more skilled in beetle identification.

The branch hopes to offer another BioLinks workshop next year on a different group of invertebrates.

Dr Sue Howarth FRSB

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Our branches need you!

Western, Beds, Essex and Herts, East Anglia, Northern and North Wales branches are recruiting new committee members and officers. Whether you are a university student, researcher, amateur enthusiast or professional biologist, joining a committee is your opportunity to organise and support the sort of events and activities you would like to see in your region. Contact regions@rsb.org.uk for more information.

BIOFEEDBACK

Readers' letters

The Dallol volcano, Ethiopia, is at the heart of a dispute between groups of scientists over whether its caustic waters support archaeal life

The complete picture

LIPIDS OVERLOOKED

I have just finished the latest (10th anniversary) issue, which was, as usual, a delight to read and well up to the usual high standard.

I was moved to comment on the interesting and excellent article by Nicholas Robinson on the subject of archaea – 'The Rise of the Ancients' (*The Biologist* Vol 66(5) p16).

Most of the articles that I have read on this topic have discussed the versatility of these organisms and their ability to survive in widely differing habitats only in terms of the robustness of their proteins, as well as aspects of their nucleic acids. This is certainly the emphasis in Nicholas Robinson's article. The role of their unique membrane lipids are no less important.

Archaea possess lipids with unique structures found nowhere else as far as I know, and these contribute significantly to the special properties of archaeal membranes and their ability to enable the organisms to function well in such diverse habitats.

Briefly, in the lipids of bacteria and eukaryotes that have a glycerol backbone, that backbone is derived from sn-glycerol-3-phosphate. Archaeal lipids are unusual in that the backbone is derived from sn-glycerol-1-phosphate. The evolution of this difference, relating to different glycerol phosphate dehydrogenases that produce different chiral forms of glycerol phosphate from dihydroxyacetone phosphate, is not yet completely understood.

In addition, the lipid side chains attached to positions 2 and 3 of the glycerol backbone are isoprenoids rather than fatty acids. These are attached to the glycerol by ether rather than ester linkages.

This makes a more chemically stable molecule compared with other more common lipids. One archaeal lipid has double isoprenoid chains linked to glycerol and the resulting molecule forms lipid assemblies that span the whole of the membrane, as distinct from the more usual bilayers.

This, too, contributes to the remarkable properties of archaeal membranes, which, combined with the special properties of their proteins, goes some way to explaining how these organisms have adapted to such a diversity of habitats.

Please forgive me for being so wordy, but I think the importance of lipids in membranes – and especially the unusual structures of archaeal membranes – have been strangely overlooked by a majority of researchers and commentators, giving an incomplete picture of these fascinating organisms.

Dr M I Gurr FRSB

NEARLY NEW...

As an avid reader of *The Biologist* since 1971, may I take this opportunity to congratulate you on the superb articles with excellent illustrations.

I am thrilled to see my name included in: 'A celebration of RSB Life Members' (*The Biologist* Vol 66(5) p43). Although the use of the heading 'New Members' on the top right is not intentional, it tends to demean the historic purpose of printing this unique list of Life Members. I shall be 91 in December, so please take my criticism in a very friendly manner!

Andrew Dawson CBiol MRSB

Contact us

Send your comments to Biofeedback, Royal Society of Biology, 1 Naoroji Street, Islington, London WC1X 0GB
Alternatively, email **tom.ireland@rsb.org.uk**
The Biologist reserves the right to edit letters where appropriate.

CORRECTIONS AND CLARIFICATIONS

In the last issue the name of the reviewer of *The Essential Guide to Rockpooling* was missing (*The Biologist* Vol 66(5) p49). The review was by Dr Ian Lancaster MRSB. We also mistakenly left the page heading 'new members' on our one-off list of life members (see above).

CROSSWORD

The biology brainteaser

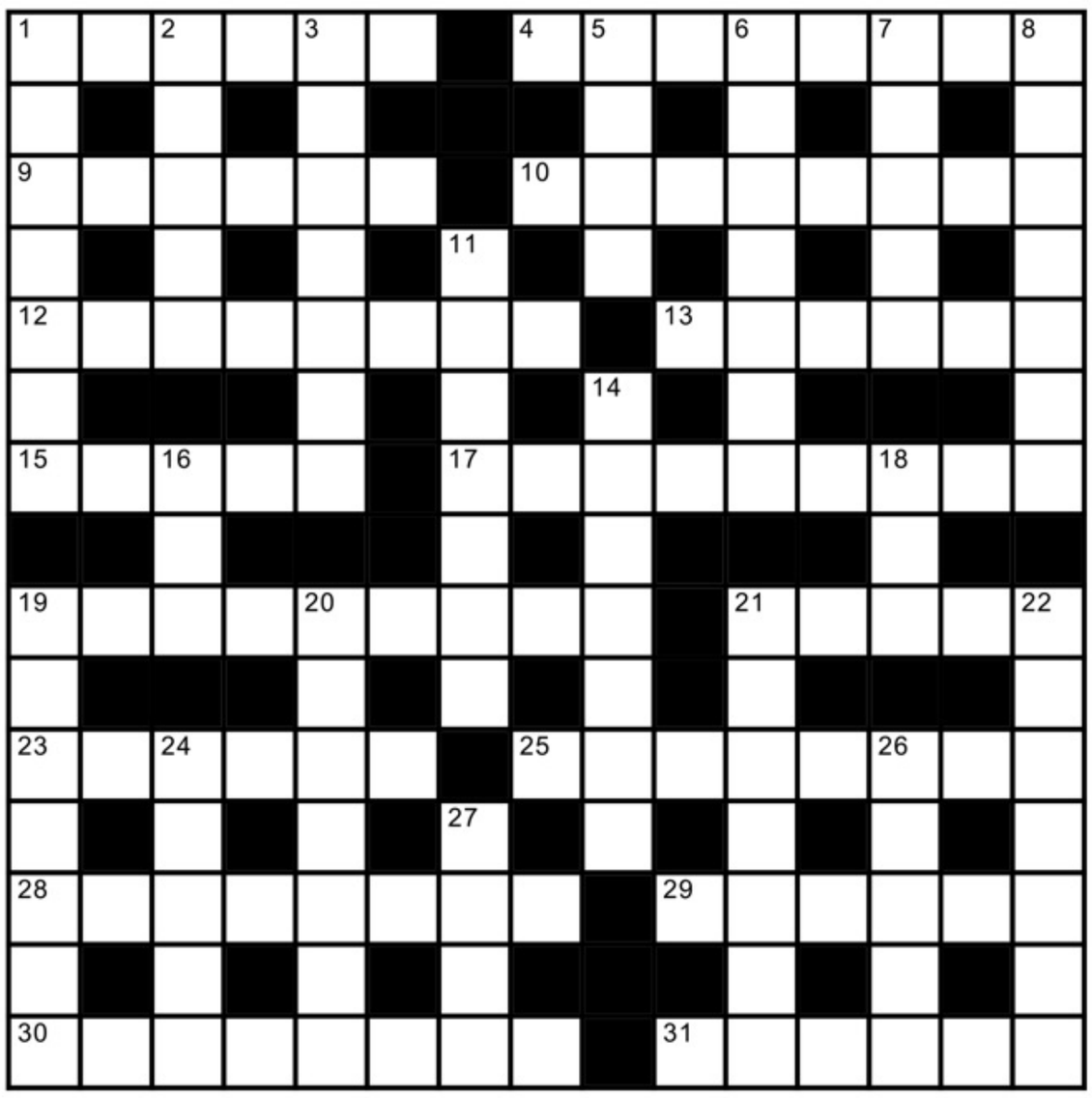
You'll be in your element with this edition's chance to win a £25 book token

Across

1 Land mollusc to shed skin (6)
4 Quickest way of building trust with head of company (8)
9 I'd trouble with ex – thick skin to show for it (6)
10 Area of old Rome can appear in photograph (8)
12 Man captures deserter, it's a long chase (8)
13 Mob starting to throw rocks, never good (6)
15 Nervous tree cutters initially make a V shaped cut (5)
17 Some hassling strikers can throw stones (5-4)
19 Capricious cow's calf not back? One always lags behind (9)
21 Permitted to turn up where one can stay (5)
23 Mate ready and tidy (2,4)
25 Where one could be travelling astern (5,3)
28 University town in USA has dance, it helps one exercise (4-4)
29 Fertiliser makes sap rise around base of plant (6)
30 Improperly dried after just hint of sun, not as fit for purpose (8)
31 Look at that bit of lavender in bed (6)

Down

1 Swan around back of Palladium to find impresario (7)
2 Their odd bits are different (5)
3 Heads of government don't usually trust councils to pay own share of costs (2,5)
5 A kiss is intended to deceive (4)
6 One might drive wildly or gad about (4,3)
7 Charlie in such trousers? (5)
8 Later after work teetotaller gulps back gin (7)
11 State roughly where the responsibility lies (3,4)
14 Gear you wear outside of town. Precisely (5,2)
16 While I am not in it ... (3)
18 ... temperature is warm (3)
19 Thus test with no end time does calm one (7)
20 Trained expert in music format (7)
21 Popular song with me did strike a chord (3,4)
22 Girl ate doughnuts – having swallowed, felt disgusted (7)
24 What's this inside of belly (5)
26 Ask about old military hat (5)
27 Pipe? Smoke outside (4)



Volume 66 No 6

Compiled by Doug Stanford

This issue

We end the year with a different challenge. Every answer contains at least one letter O representing oxygen and at least one letter H for hydrogen (not necessarily adjacent). Clue definitions refer to the complete word whereas the secondary indication refers to the word minus both a single O and a single H. Thus CO-HOST (secondary indication for COST) might be clued as, 'Expense of acquiring second presenter'. One answer is an abbreviation.

How to enter

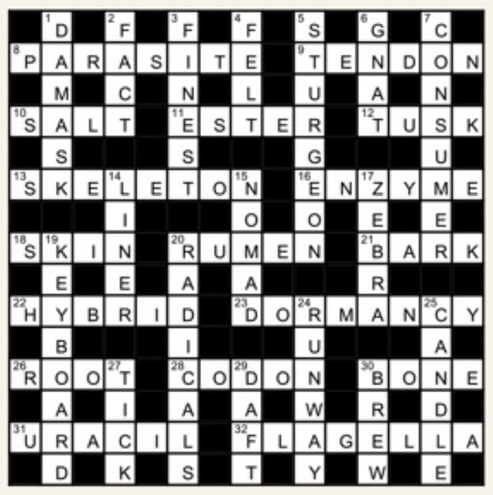
To be in with a chance of winning, send us your completed puzzles by 11th January 2020. Please include your name, address and membership number with your entry – an email address would be handy too. Post your entries to: Crossword, The Biologist, Royal Society of Biology, 1 Naoroji Street, Islington, London WC1X 0GB

Last issue's winners

Well done to last issue's winners: DR KWG Shillam CBiol FRSB and Dr Andy McLeod FRSB. £25 book tokens are on their way to you.

Last issue's solution

Vol 66 No 5



MUSEUMPIECE

Biological exhibits from around the world

#40 The K-Pg boundary

Manchester Museum, UK

A large lump of sandstone in Manchester Museum contains a slice of history – quite literally – from one of the most talked-about events in the biogeography of Earth.

Around 66 million years ago the Cretaceous–Paleogene, or K-Pg, extinction (formerly known as the Cretaceous–Tertiary, or K-T, extinction) wiped out three quarters of Earth's flora and fauna, including the dinosaurs.

It is now generally thought that the mass extinction was a result of the enormous Chicxulub asteroid impact on a region that is now the Yucatán Peninsula of Mexico. The thin layer of rock representing this turbulent period on geological samples is known as the K-Pg boundary (formerly known as the K-T boundary).

The specimen (pictured) in Manchester Museum was collected by Dr John Nudds, former curator of the Manchester Museum, from the Geulhemmerberg cave in Maastricht, the Netherlands, in 2001.

Rock found in this marine cave features an unusually thick clay layer set down in the immediate aftermath of the impact. The thickness of the boundary layer means more fossilised shells for analysis, helping researchers better understand the 1,000 years that followed the impact.

Using data from Geulhemmerberg samples, researchers were able to clarify that the asteroid, which produced a crater 150km wide, caused a global drop in the pH of the oceans – probably from the displacement of vast amounts of sulphurous rock. Plankton that form calciferous shells, a key part of the marine food chain, were disproportionately affected by the acidic conditions. The impact of this on marine ecosystems subsequently changed the entire planet's carbon cycle, from which life on Earth took millions of years to recover.

The clay from this extraordinary time can be seen as a darker grey layer in the brown sandstone. The specimen is on permanent display in the fossils gallery of the museum, part of the University of Manchester.

www.museum.manchester.ac.uk/visit
Entry is free. Open 10:00–17:00 every day

Royal Society of Biology

10 YEARS | A Decade of Growth

Anniversary Gala Dinner

3 March 2020 | Science Museum, London

Join us in celebrating the biosciences and the lifetime achievements of our Honorary Fellow **Sir David Attenborough**

RSB Members: £60-£180 | Non-members: £240
Corporate tables available

Proceeds from this event will help the RSB's ongoing work supporting the global biosciences community

Tickets now on sale: rsb.org.uk/gala

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Published in partnership with the Royal Society of Biology, Oxford Biology Primers encourage students to explore biology for themselves.

They are the only resource to introduce prospective and current students of undergraduate-level bioscience to a range of topics from this dynamic experimental science, enticing them to study further.

PUBLISHING IN 2019

Human Infectious Disease and Public Health | *William Fullick* | January

Plant Diseases and Biosecurity | *Paul Beales, John Elphinstone, Adrian Fox, Charles Lane, Derek McCann, Tim Lacey, Julian Little, Kerry Maguire and Alice Turnbull* | February

Hormones | *Joy Hinson and Peter Raven* | June

Conservation: a people centred approach | *Francis Gilbert and Hilary Gilbert* | July

Synthetic Biology in Mammals | *Jamie Davies* | December

Cancer Biology and Treatment | *Aysha Divan and Janice A Royds* | December

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