Biology News

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UNIVERSITY OF OXFORD

Department of Plant Sciences
Department of Zoology

George Ratcliffe

Head of Department of Plant Sciences

No one can accuse us of being reckless. First suggested, to the best of my knowledge, in 1994, formally proposed and deemed unworkable in 2006, and finally approved in 2018, the conversion of the Biological Sciences degree into a four year course is almost upon us. We shall be welcoming the first undergraduates on to the new course in October, and for the first time they will have the option of staying on for a fourth year to undertake a much more substantial research project than has been possible hitherto. We have reached this point, albeit about a century after Oxford chemistry, through the joint efforts of many people in both Plant Sciences and Zoology, and much work is now underway to ensure that we shall be ready to deliver the many innovative aspects of the course when the first cohort arrives. This is a significant milestone in the teaching of Biology at Oxford, and one that should bring substantial benefits to our students when they graduate.

Another exciting development with far reaching consequences has been the decision to include Plant Sciences in the replacement for the Tinbergen Building, the former home of Experimental Psychology and Zoology. The University has approved £192 million in capital funding for the project, with additional funding to be raised through donor philanthropy. The working title for the new building is the Centre for Life and Mind Sciences, and it will be designed by the architects NBBJ. Co-location will enable Plant Sciences and Zoology to form a new Biology department, and discussions are underway to create a departmental structure that will build on the undoubted strengths of the two existing Departments.

There is also good news in relation to academic appointments. The health of our discipline hinges on maintaining a critical mass of researchers with an interest in plants. The premature death of Ian Moore was a great loss to our research profile, but happily agreement has been reached more rapidly than might have been expected to refill the post, again in association with Wadham. Ian made some seminal discoveries in plant cell biology and we hope to appoint someone in the same field. This appointment will return us to full strength, but in a further development the University has also approved an entirely new post, this time in the field of Bioinfomatics. We have had a bid from The Queen's College for association with this post and we expect this to be approved by the University in the next few weeks. The creation of a new tutorial post, together with two others based in Zoology, is an important step towards our strategic goal of ensuring that each college that admits Biology students should have two tutorial fellows in the subject.

There is little space left to report the exciting science that we have been pursuing in the last year, so first let me reassure you that my colleagues continue to advance our understanding of plant biology in all its many aspects, and secondly draw your attention to another milestone: the launch and commercialisation of BRAHMSv8. BRAHMS is a botanical research and collection management tool that sets an international standard for the curation and management of plant collections. The software has been developed over many years in the Oxford University Herbaria, and the completion and licensing of Brahmsv8 is the culmination of a major effort by two members of staff, Denis Filer and Andrew Liddell.

Also in relation to the Herbaria, I should like to highlight a boost for the digitisation project, in the shape of a generous gift from Clive Gillmore to digitise three areas of the collections, including the original 1660 herbarium assembled by Bobart the Elder. In June, we shall launch an appeal to alumni to support further digitisation, followed by a wider crowdfunding appeal in October. A digital giving campaign seems particularly appropriate for a project that will use digitisation to enhance still further the value of the Herbaria as a contemporary research tool.

Finally you can keep in touch via our website and blog (plants.ox.ac.uk), Twitter and Instagram (@OxfordPlants).

George Ratcliffe
Professor of Plant Sciences

Ben Sheldon

Head of Department of Zoology

As I write this piece on a surprisingly spring-like Thursday morning in mid-February, I could, if I chose, listen to one member of the Department of Zoology (Dr Tristram Wyatt) on In Our Time on Radio 4, speaking on the fascinating topic of pheromones. Or, if I switched BBC1 on, I could watch two other members of the department, Professor Sunetra Gupta and Dr Kayla King, being interviewed for a news segment talking about their work on a new flu vaccine, and on the far-reaching effects that the communities of microbes that inhabit our bodies have, respectively. While it is not often that we dominate the national broadcast media to quite this extent, this anecdote illustrates just some of the external reach of our activity here in the Department of Zoology.

Our external reach is important for many reasons, of which I want to highlight three here. First, we continue to view the dissemination of knowledge as broadly as possible as one of the key responsibilities of all academics. Some take naturally to the broadcast media, others to print, in short or long form, others are masters of newer forms of digital social media. In the latter sphere the department has been particularly helped by Caitlin Hamilton who works as Communications and Outreach Officer across Plant Sciences and Zoology, and who has done much to revitalise our websites, social media feed and Open Days (a staggering 700 people attended the most recent one – a sign of the great interest provoked by the new four year Biology course that George Ratcliffe outlines in his piece).

A second reason for reaching outwards is that we consider that the relevance of our science and, indeed of University activity more generally, to society as a whole needs to be stressed and shared as widely as possible in what are somewhat turbulent times. One of the considerable perks of being Head of Department is being able to see the depth and breadth of activities across the department, and being able to share those in a range of fora. The breadth of wider impacts of research originating in Zoology surprises many, as it ranges from conservation success stories and policy development through the development of new methods for assessing animal welfare, the development of methods to characterise and forecast disease epidemics, vaccine development and commercial spin-outs in areas as diverse as genetic control of pest insects to multi-million pound video gaming. A fuller list can be found at www.zoo.co.uk/impact.

Finally, this is a most exciting time for Biology at Oxford, and we're keen to share this as widely as possible. As both Tim Coulson and George Ratcliffe outline elsewhere, the University has made a huge commitment to the future of the subject in Oxford in terms of supporting a new building that will house Biology. We are all excited by the opportunities an entirely new undergraduate course provides, and by the new academic posts that have been approved to support that. The success of both ventures relies on recruiting and supporting the best academic and research staff, and equally, graduate and undergraduate students, from all sources, and I'd urge you to spread the message about these new developments as widely as possible.

Ben Sheldon
Luc Hoffmann Professor of Ornithology, Director of the Edward Grey Institute

Pre-clinical success for a universal flu vaccine offers hope for new third generation approach

Development of a vaccine candidate with potential to save millions worldwide will be accelerated in commercialisation deal with Blue Water Vaccines.

The antigenic evolution of influenza is thought to occur by a process of "drift", where mutations in highly variable epitopes in the head domain of the major influenza antigen, haemagglutinin (HA), allow the virus to escape host population immunity. However, this assumption is difficult to reconcile with the observation that each influenza season is dominated by a single influenza strain. This paradox is typically resolved by imposing some form of arbitrary constraint or rate limiting factor on the mode and tempo of viral mutation. Our research group has hypothesised by contrast (and somewhat controversially) that constraints on the antigenic evolution of influenza arise primarily through strong immune selective pressure on epitopes of 'limited variability'.

We have recently identified one of these epitopes of limited variability in the head domain of the H1 HA protein. We have shown that children aged 6–12 years exhibit periodic historical immunity mediated by one conformation of this epitope. Mutagenesis of one epitope conformation into another removes or reduces this cross-reactivity. We have demonstrated that vaccinating with this epitope in mice induces an identical pattern of cross-reactivity to that shown by the children, and that an epitope contained in the H1N1 influenza strains circulating in either 2006 and 1977 protects mice against challenge with a strain that last circulated in 1934!

Due to the nature of these epitopes – they are highly immunogenic and limited in variability - they are also ideal vaccine targets. Vaccinating against five conformations of the epitope induces immunity to all historical strains circulating since 1918. Our work presents, as far as we know, a unique example of where a mathematical model of the evolutionary dynamics of an infectious disease has led to the experimental identification of a novel vaccine target.

Our approach won a Royal Society Translational Award in 2017, and Dr. Craig Thompson has just won the MPLS Early Career Impact work in recognition of this achievement. Very excitingly, Oxford University, through its innovation arm Oxford University Innovation (OUI), has entered into an option agreement for a universal influenza vaccine with US-based startup Blue Water Vaccines (BWV), which is raising $15m to support development of this universal flu vaccine.

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> ***"Our work presents, as far as we know, a unique example of where a mathematical model of the evolutionary dynamics of an infectious disease has led to the experimental identification of a novel vaccine target."***

© Charlie Lee-Potter

Sunetra Gupta
Professor of Theoretical Epidemiology

Nature-based Solutions to Global Challenges

Leaders and scientists across the globe are starting to recognise that we need to work with natural ecosystems to solve many major global challenges.

Nathalie Seddon
Professor of Biodiversity

Protecting and restoring ecosystems can help increase our resilience to climate change impacts and store carbon to slow warming. It also protects biodiversity and enhances the natural resources on which we depend for our health, wealth and wellbeing. However, science-based targets for nature-based solutions barely feature in climate policy, are rarely implemented and receive very little funding. Consequently, we continue to lose our forests and destroy our coastal habitats at ever-increasing rates.

There are three key reasons for this. First, scientific evidence for nature's benefits is hard to access and difficult to understand. Second, there is limited knowledge exchange between scientists, policy makers and those working on the ground. Third, there is a lack of awareness in business and government of our fundamental dependency on nature and consequently a lack of finance to support nature-based solutions on the ground.

To address these issues, alongside partners from the conservation and development sectors, we have established a new interdisciplinary programme of research, research translation, policy advice and education called the Nature-based Solutions Initiative (NBSI). We collate, consolidate and communicate scientific understanding of the effectiveness of nature-based solutions for the benefit of current and future decision makers in business, government and civil society.

> ***"The aim of the NBSI is to improve understanding of the value and limits to nature-based solutions to global challenges, with a particular focus on grounding climate policy and practice in sound biodiversity science."***

The aim of the NBSI is to improve understanding of the value and limits to nature-based solutions to global challenges, with a particular focus on grounding climate policy and practice in sound biodiversity science.

We launched the initiative in 2018, and presented our work at various climate and development meetings throughout the year. Of particular importance were the Adaptation Futures conference in Cape Town and the United Nations Framework Convention for Climate Change COP24 meeting in Poland, where nature-based solutions were prominent for the first time.

Presentations at these events included our animation explaining the role of nature-based solutions to climate change impacts, as well as our interactive online policy platform, which makes information about climate change adaptation planning across the globe openly available, easy and interesting to explore. The platform includes country by country details of who is doing what, in terms of incorporating nature-based solutions into climate pledges.

© NBS Riopaz

The platform will this year be linked to a set of interactive tools to visualize the science evidence-base on the effectiveness of nature-based solutions to climate change impacts. Our ultimate goals are to increase ambition for nature in climate change policy and to bring nature-based solutions, informed by science, closer to the centre of the sustainable development agenda.

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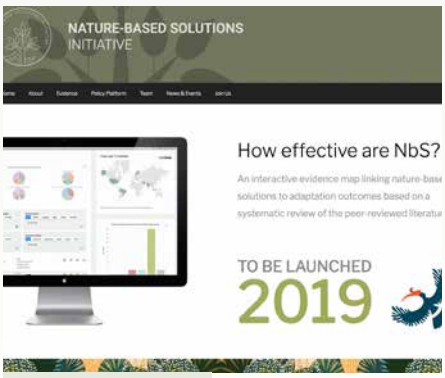
Ridge way mangroves



nbspolicyplatform.org

The evolution of nitrogen fixing bacteria

How can we use evolutionary processes to understand the symbiosis between legumes and their microsymbionts the rhizobia?

N_2 gas is everywhere. Well, it constitutes 78% of the atmosphere, but is not available to biology. It needs to be fixed and reduced to ammonia for organisms to assimilate it. The main way it is fixed is by the enzyme nitrogenase that catalyses the 8-electron reduction of N_2 and $2H^+$ to $2NH_3$ and H_2. This enzyme is only found in prokaryotes, whether bacteria or archaea and probably appeared early in the evolution of life (possibly 2.2–3.5 billion years ago) in an environment lacking oxygen. So in our current atmosphere of 21% oxygen it needs protection from oxidation.

Skipping forward to the evolution of land plants around 470MYA they would have relied entirely on ammonia, nitrate and other reduced nitrogen produced mainly by free-living bacteria and archaea. However, around 100MYA a remarkable thing happened – probably in response to increasingly limited reduced nitrogen available in the biosphere – where just four orders of plants, all clustered in the eurosid clade, evolved the formation of root nodules that are packed with nitrogen fixing bacteria. This transformed life on earth with a massive input of biologically available nitrogen into the biosphere.

One group you may not have heard of are the actinorhizal plants (spanning three of the four orders), such as alders and casuarinas but the largest group are the legumes (fourth order Fabales with one family the *Fabaceae* that nodulates). Legumes constitute the third largest family of flowering plants, with over 13,000 species, and they are now essential to life on earth as we know it. This is because the bacteria in their roots known as rhizobia provide the largest single contribution of nitrogen to land plants, supporting anywhere up to 30–40% of the land's biosphere. This is the little niche I work in, trying to understand the symbiosis between legumes and their microsymbionts the rhizobia.

My approach is dominated by bacterial genetics and physiology, where we examine how the rhizobial bacteria colonise plant roots and induce the formation of nodules in the plant and go on to fix N_2. Using bacterial mutants, we examine how rhizobia secrete the fixed nitrogen as ammonia to the plant and in return receive a carbon and energy source as dicarboxylic acids from the plant. We also work on how this remarkable process might be transferred to cereals to help feed a burgeoning global population.

"However, around 100MYA a remarkable thing happened, probably in response to increasingly limited reduced nitrogen available in the biosphere, where just four orders of plants, all clustered in the eurosid clade, evolved the formation of root nodules that are packed with nitrogen fixing bacteria."

Pea plant

Philip Poole
Professor of Plant Microbiology

Plant and pollinator hyper-diversity in the Greater Cape Floristic Region biodiversity hot-spot

Explaining species coexistence is one of the most fundamental challenges for ecological science.

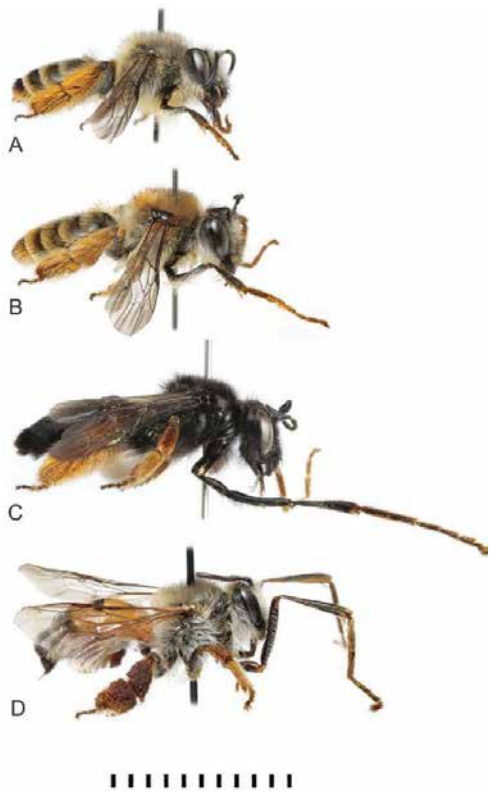
In most ecosystems there are a number of species that appear to occupy the same or overlapping ecological niches. If this is the case, we expect species to compete directly for resources, and for one to eventually gain an advantage and drive the other to extinction. However, contrary to these expectations, species with overlapping niches are frequently found to coexist.

Species coexistence can be explained in terms of deterministic (e.g. competitive exclusion / niche differentiation), neutral (when species are ecologically equivalent) or historical (patterns of speciation and dispersal) processes. A fourth alternative is that co-occurring species facilitate each other's acquisition of resources, rather than, or in addition to, competing.

For example, if plant species individually offer only part of the range of rewards that pollinators are foraging for (pollen, nectar, oils, scents), pollinators would visit multiple species to meet their foraging needs, which would lead to multiple plant species receiving the pollination services they require. We are investigating whether plant-plant facilitation based on complementary resource provision for pollinators is one of the mechanisms supporting high within-site plant species diversity in the Greater Cape Floristic Region biodiversity hot-spot. We are doing this using plant-pollinator community network analysis, where network link strength is based on analysis of the rewards the plants are providing to the pollinators, and analysis of pollinator efficacy in pollen delivery to plants. This network analysis provides a means of quantifying the strength of interaction between species, and modelling how the network changes, and what happens to remaining species in a community, following addition or extinction of species.

Dr Tonya Lander
Leverhulme Early Career Fellow

The work currently focuses on specialist *Rediviva* oil-bees (Melittidae), and their *Diascia* oil-plants (Scrophulariaceae) in the Hantam Botanical Garden and the Avontuur Nature Reserve near Nieuwoudtville, South Africa. Females in the *Rediviva* genus collect oil from a range of oil-producing flowers, mainly in the *Diascia* genus, and visit other plants for nectar. The system appears to provide an example of complementary resource provision for pollinators as a mechanism supporting high within-site plant species diversity. This research has been funded by The Leverhulme Trust, The Gatsby Foundation, The British Ecological Society, and The Eva Crane Trust.



Female Rediviva bees in lateral view showing species specific variation of foreleg

D Whiteheadii

Warriors, Women & Wildlife: Conserving Lions in Tanzania's Ruaha landscape

We celebrate a decade of the Ruaha Carnivore Project by talking with director Dr Amy Dickman about her work on large carnivore ecology and conservation.

Lions are one of the world's most iconic species – 40,000 years ago people carved lion figurines from woolly mammoth ivory; lion behaviours are depicted in cave art from over 30,000 years ago, and more countries (including the UK) have lions as their national animal than any other species. However, they are under grave threat: lion numbers have nearly halved in 20 years, and the latest data suggest there are now fewer wild lions in Africa than rhinos. Key threats driving lion declines include loss of habitat and prey, and conflict with local communities.

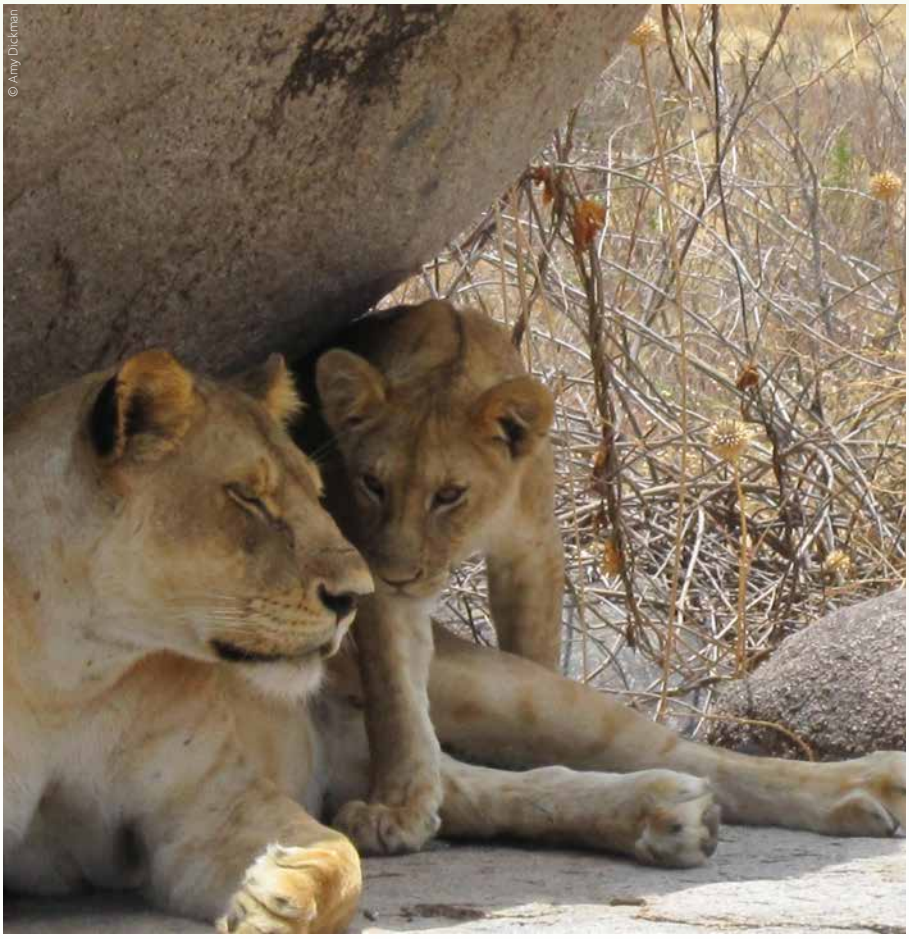
Tanzania's vast Ruaha landscape is one of only five populations worldwide that still have at least 1000 lions, and represents a microcosm of the global threats to lions. Across Africa, around half of the lion range is outside protected areas, and in Ruaha, lions use land occupied by extremely poor pastoralists and subsistence farmers. We found that lions threatened people and their stock (crucial economic and cultural assets in these vulnerable populations), and provided no benefits for most rural villagers. People only benefited from dead lions, as warriors received wealth and status for killing them. Unsurprisingly, people frequently speared, poisoned or snared lions, creating a major conservation issue.


© Jon Erickson

Amy Dickman and Barabaig warriors

> ***"We help villagers better protect their livestock, using fortified enclosures and specialised livestock guarding dogs."***

In 2009, under a Kaplan Senior Research Fellowship at the Zoology Department's Wildlife Conservation Research Unit (WildCRU) and Pembroke College, I established the Ruaha Carnivore Project to research large carnivore ecology and conservation. We help villagers better protect their livestock, using fortified enclosures and specialised livestock guarding dogs. Crucially, people need meaningful benefits from wildlife, so we equip healthcare clinics, invest in local schools, provide scholarships and school feeding programmes, and support veterinary services. To link benefits directly to wildlife presence, villagers place camera-traps, and receive points per wild animal photographed. Points translate into additional community benefits, and wildlife is now a major driver of community development. We developed an initiative based on the 'Lion Guardians' model, where warriors maintain their traditional protective roles, but gain wealth and status through lion conservation rather than killing. Meanwhile, we engage and empower women and girls, to encourage them to support conservation, and use data from our ecological research to identify conflict hotspots and prioritise mitigation efforts. This research – far in every way from academic ivory towers – substantially reduces conflict, empowers communities and helps address the conservation threat facing this truly iconic species.


© Amy Dickman


© John Cairns

Dr Amy Dickman
Kaplan Senior Research Fellow in Wild Felid Conservation

Tracking the drivers of puffins' declines

Atlantic puffins have been declining for decades and are now endangered in Europe. Annette Fayet, seabird scientist and marine ecologist, tries to find out why.

Dr Annette Fayet
Junior Research Fellow,
The Queen's College

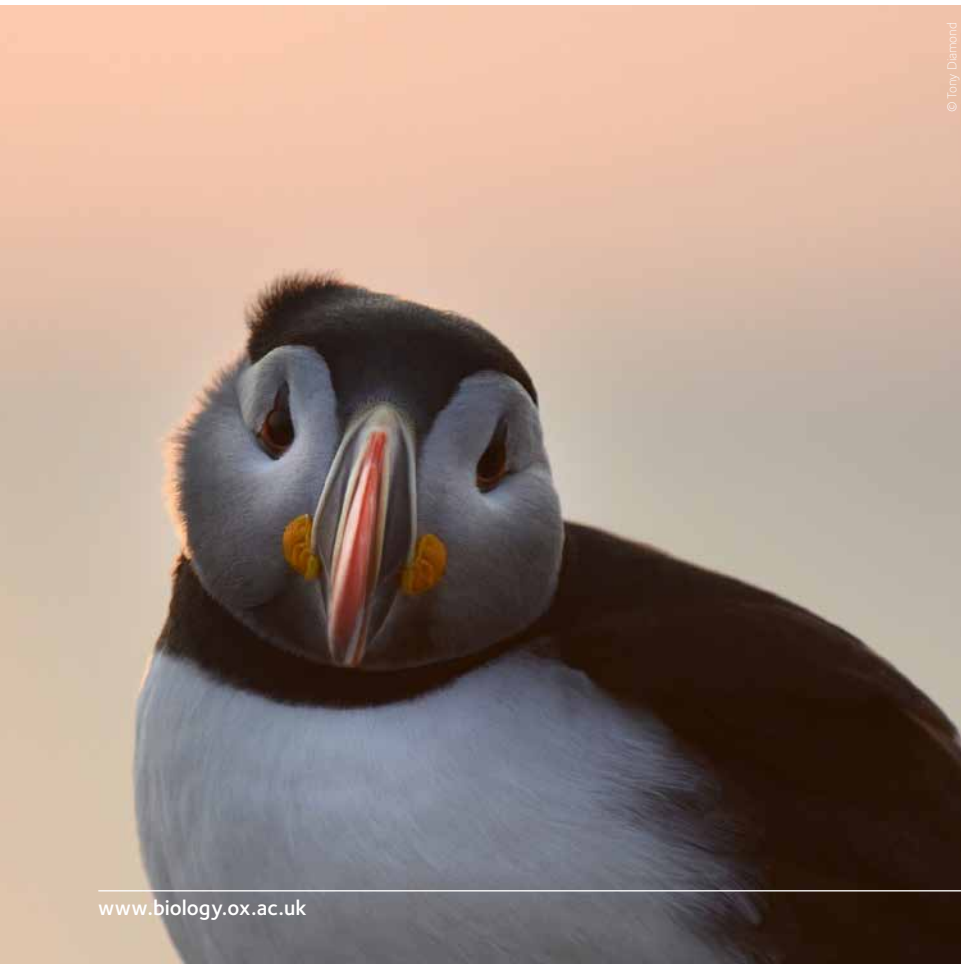
Atlantic puffins are a key species of North Atlantic breeding seabird, with large colonies in the UK, Norway, and Iceland. In the last few decades many populations have been declining dramatically, especially in the northern part of their range. This is likely linked to the availability of resources, but the feeding ecology of the species is poorly understood, making it difficult to identify the drivers of these declines.

Following the movements of seabirds at sea require miniature tracking loggers which can be fitted on the birds to record their locations. I also use advanced analytical techniques to infer the birds' behaviour from their movements, to understand how they use the ocean's resources. Breeding puffins are sensitive, so to track their feeding movements without disturbance, tiny, very light loggers are required. These recently became available, and I was able to start tracking puffins' chick-provisioning trips. To obtain a complete picture of their feeding ecology, I combined the loggers with nest-based cameras to follow their breeding behaviour, and collected faecal samples. These will be analysed with novel DNA metabarcoding techniques by Gemma Clucas – a Zoology alumni now at the Cornell University – and will allow us to investigate the birds' diet.

I started the study in June 2018 on Skomer Island (Wales), one of the few colonies where puffins are thriving. I then went to Røst (Norway), where the population of 1.8M pairs has declined by 80% since the 1970s and not a single chick fledged for 10 consecutive years in the 2000s. I continued on Grimsey, northern Iceland, with good breeding success, and finished in the Westman Islands (southern Iceland), the world's largest puffin colony, where for two difficult weeks I witnessed young chicks starve to death one by one.

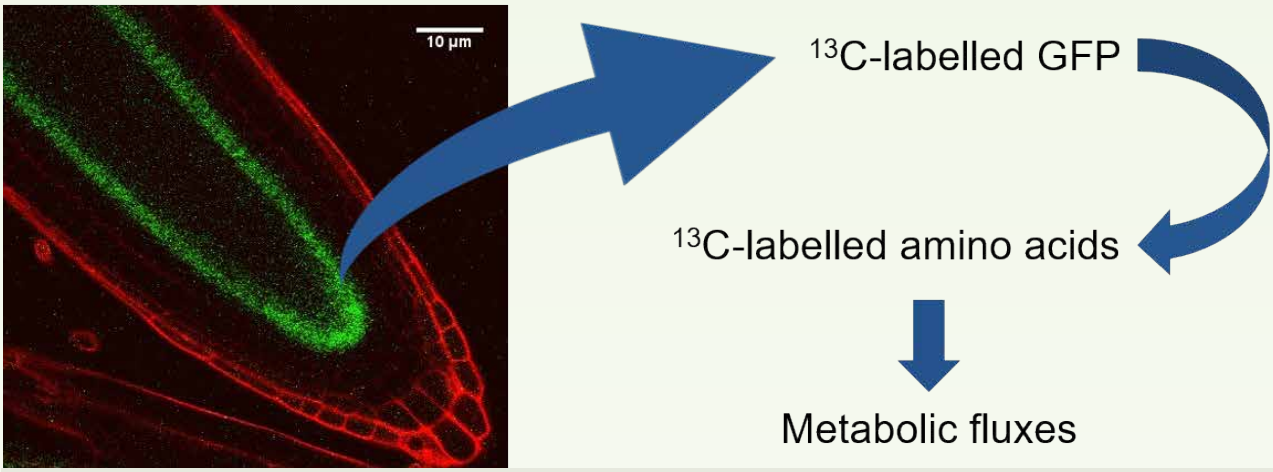
The analysis is still in progress but preliminary results show that on colonies where birds struggle to breed, they have to fly very long distances to find food – well beyond what would make a trip worthwhile in terms of energy gain. As such, chicks may not get enough food and parents may exhaust themselves. Even on successful colonies, birds fed further than expected, which has important implications for the protection of local waters around colonies. The next steps are now to identify the causes of fish stock depletion near northern colonies and to implement appropriate conservation measures.

> ***"Breeding puffins are sensitive, so to track their feeding movements without disturbance, tiny, very light loggers are required."***



Annette with a puffin in Iceland

Plant metabolic phenotypes



Cell-type specific expression of a labelled protein, such as GFP, followed by purification provides a method for cell-type specific metabolic flux analysis.

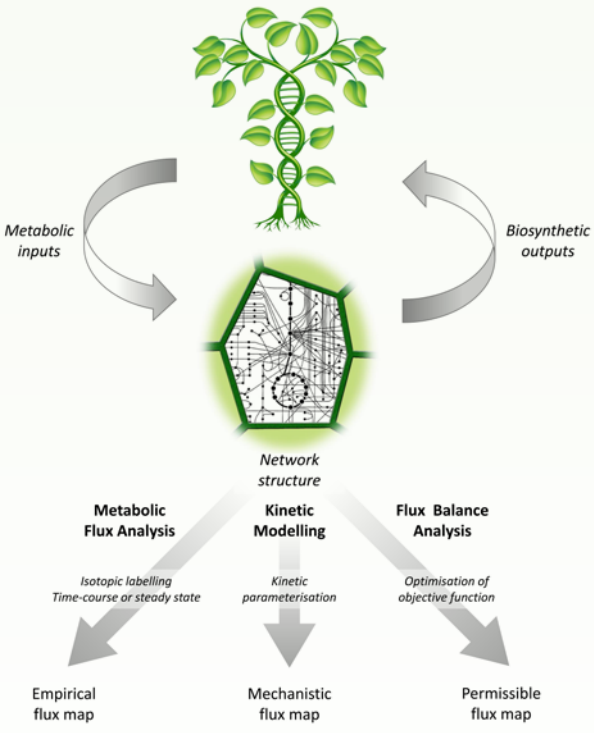
The flows of material through metabolic pathways are fundamental to the functions of cells and the survival of organisms. Classically, measurements of metabolic fluxes focussed on a specific pathway, for example measuring the rate of photosynthesis in an illuminated leaf. However each conventionally defined pathway is embedded in a wider network of enzyme-catalysed reactions, and a system-wide view of the operation of the network is required if we are to understand the relationship between the nutritional inputs of a cell and the metabolic outputs. Investigating fluxes across the whole network takes on particular significance when analysing the factors that determine plant growth and the productivity of crop plants.

> ***"Measuring multiple fluxes is experimentally challenging"***

Working closely with Nick Kruger and Lee Sweetlove, my research is based on the development and application of methods for the measurement and prediction of multiple metabolic fluxes in plant cell metabolic networks. Measuring multiple fluxes is experimentally challenging and requires stable isotope labelling experiments; while predicting fluxes requires the construction of metabolic models. The aim is to construct flux maps that can be used to answer fundamental questions about network structure, capacity and performance.

Empirically-determined flux maps are useful for testing hypotheses, while predicted flux maps are useful for proposing them. As examples, we have used empirically determined flux maps to show that the inclusion of ammonium in the growth medium of a cultured *Arabidopsis* cell line increased the cost of cell maintenance, thus supporting the futile cycling hypothesis of ammonium toxicity; and we have used the modelling approach to predict that transferring the water-saving Crassulacean acid metabolism (CAM) trait to the leaves of C3 plants should be possible without compromising productivity, despite the extra energetic cost of running CAM photosynthesis.

The major challenge now is to extend these methods to questions that arise in complex cellular systems. What is the impact of cell specialisation in differentiated tissues on metabolic phenotypes? How do plant and microbial cells adapt metabolically when they form an association? We have developed a technique for cell-type specific flux analysis to answer these questions, but it requires improvements in analytical sensitivity before it can be used routinely. At a more abstract level, there is also the question of whether metabolic fluxes can be sensed by cells for the purposes of regulation. Are metabolic fluxes detectable by cells, or are they just a convenient way in which investigators can classify the metabolic phenotype?



Overview of metabolic flux analysis. [From N.J. Kruger and R.G. Ratcliffe (2015) Biochemical Journal 465, 27–38]

George Ratcliffe
Professor of Plant Sciences

The Aldabra Clean-Up Project

Students from across the University are leading an expedition to the remote Aldabra Atoll to remove tonnes of ocean trash from its shores

April Burt
Graduate student in the Department of Plant Sciences

In May 2018 the Aldabra Clean-Up Project was launched, supported by The Queen's College Oxford, at the Royal Society in London. The project is a collaboration between Associate Professor Lindsay Turnbull and the Seychelles Islands Foundation, where Lindsay has served for many years as a trustee. It brings together Oxford postgraduates and committed Seychellois volunteers to achieve an ambitious goal – the cleaning up of Aldabra Atoll in the Indian Ocean, which is badly affected by plastic pollution.

The Oxford team are all currently studying for DPhil degrees and include project leader April Burt (Plant Sciences); Rebecca Goldberg (Zoology); Thomas Zilhardt (Materials Sciences); Josie Mahony (Zoology and Geography) and Martyna Syposz (Zoology). The Seychelles team were selected through a national competition and have diverse professions, including events management and youth engagement. They are led by Jeremy Raguain from the Seychelles Islands Foundation.

Aldabra Atoll is one of the largest in the world and is home to unique species, including 150,000 Aldabra giant tortoises. But, despite its isolation and protection, this UNESCO World Heritage Site has not escaped the threat of marine plastic pollution. Large amounts of plastic have been accumulating along the coastline, including everyday items, such as toothbrushes and flip-flops. The plastic debris obstructs marine turtle nesting habitats and pollutes coastal grasslands where tortoises graze.

The project will clean up Aldabra in the only way possible, with hard work. The teams will deploy to remote field camps and systematically move along the coastline, compiling the plastic at designated sites, to be collected by chartered barge. They will also make systematic surveys of the rubbish and attempt to discover its origins, through ocean current modelling, aided by Helen Johnson from the Department of Earth Sciences. The terrain is extremely difficult, and conditions will be tough, but the team are well prepared and have spent the last year fundraising, conducting outreach activities and developing specific research aims that will inform the management of this threat to Aldabra and other remote islands. The team departed in February to join their Seychellois team mates and embark on the expedition of a life-time.

> ***"Despite its isolation and protection, this UNESCO World Heritage Site has not escaped the threat of marine plastic pollution."***

We are living in a Bacterial World

Science is lifting the lid on the secret lives of bacteria – and revealing how the smallest of organisms are the key to understanding ourselves and some of our biggest questions.

Chemical fertilisers helped to achieve a "Green Revolution" that addressed the issue of hunger in the vast majority of the world, but they have also resulted in a growing disparity between wealthy and poor farmers. In Mexico, where I am from, the decision about whether or not to use chemical fertilisers is a complex one, that needs to balance the need for high-yields against the cost of detrimental environmental impacts. This is why I decided to do my DPhil in Professor Philip Poole's lab on the topic of legume-rhizobium symbiosis, a sustainable alternative to nitrogen fertilisers. It was at this moment that I became involved with the Bacterial World exhibit.

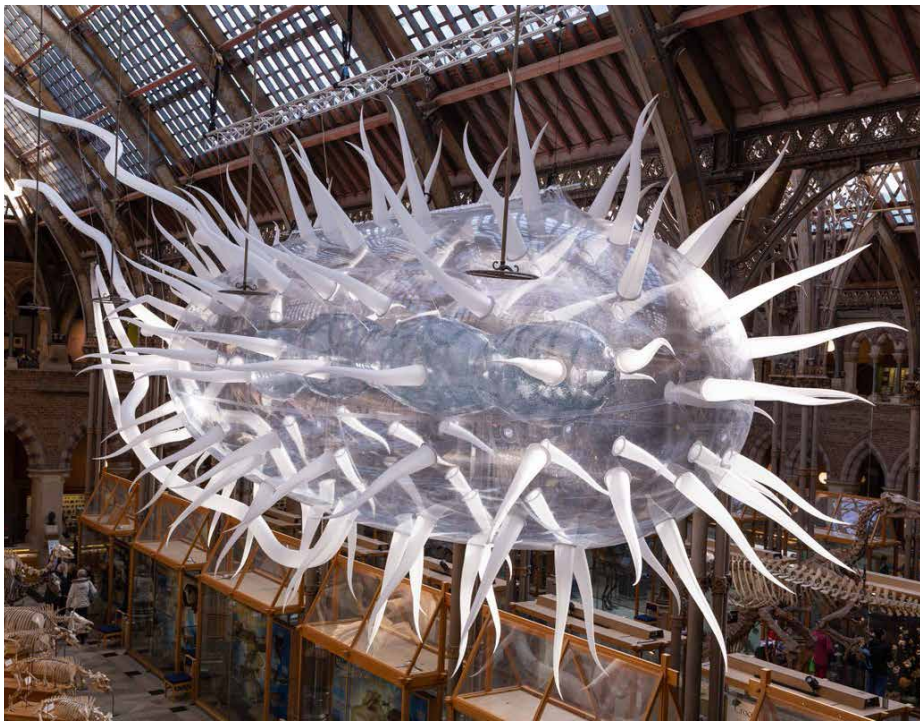
The rhizobial competition experiment that found its way into this exhibition represents a very important moment in my PhD. I was at the 'proof of concept' stage of my project, and as such I was both excited and afraid to learn the results of this experiment. A negative result would have meant needing to re-organise the ideas on which my project was based, with insufficient time to re-run experiments. A positive result, on the other hand, would have meant that achieving the target of my research - the identification of rhizobial strains with the potential to be used as inoculants in agriculture - was one important step closer. In the event, fortunately, the result was a positive one!

When you are doing research in the lab and you reach an interesting finding – a simple finding that provides concrete reassurance of progress – you often wish for an opportunity to share it more widely. Whilst alone these results are not always suitable for publication in a journal, they can help non-scientists to understand and appreciate the subject. For me, that is why the Natural History Museum's stupendous effort in running the Bacteria World exhibition is so important. Not only is it sharing with non-scientists the central role of bacteria in nature, but it is also giving scientists the opportunity to share the results of all our efforts with the public.

For me, having a piece of my DPhil in this exhibition is the scientific version of a film/tv artist winning a BAFTA!

> ***"When doing research in the lab and you reach an interesting finding – a simple finding that provides concrete reassurance of progress – you often wish for an opportunity to share it more widely."***

Marcela Mendoza-Suárez
Graduate student in the Department of Plant Sciences



Biology undergraduates enjoy getting out into their fields of study

Tenerife

Andrew Wood
Somerville

Wallace once famously said that if you can understand islands you can understand continents, and so, in April 2018 the undergraduate botany field trip sought to explore the island of Tenerife. The island's fame as a holiday destination should by no means colour anyone's judgment of the trip, for the usual buckets and spades were swapped instead for hand lenses and sturdy walking boots.

Tenerife is a biodiversity hotspot, part of a wider archipelago and a great place to explore island biogeography. The hands on experience gained gave us an understanding of the truly distinct assemblage of flora: from radiations of Sonchus and Echium to the insular woodiness of *Isoplexus canariensis*. This Canarian epithet followed us wherever we went, from the pine forests of *Pinus cararienses*, to the coastal scrubland of *Euphorbia canariensis*, tall organ-pipe shaped plants which thrive in the harsh environment. A special mention must be made to Professor Stephen Harris' for his Plant Key of Tenerife, a truly remarkable achievement for all 1500 species. This incredible knowledge was shared with such passion from all the members of staff, which really sparked enthusiasm in the students who were fortunate enough to partake. It is truly astonishing how much was packed into such a short space of time, learning how to analyse and dissect unknown flowers, examine colonisation by invasives and become semi-proficient botanists. All-in-all the trip was a resounding success and led to the creation of a new taxa of students, *Oxford canariensis*, passionate about botany and knowledgeable about (at least!) a small corner of the world: Tenerife.

Borneo

Miriam Lord
Lady Margaret Hall

Malaysian Borneo embodies the widespread tension between biological richness and its exploitation, with swathes of geometric oil palm and the scars of deforestation and mining contrasting markedly with remnants of forest below the majestic slopes of Mount Kinabalu.

Danum Vally field centre, however, lies on the edge of the Danum Valley Conservation Area, an extraordinarily diverse and beautiful region of undisturbed primary forest. The sticky heat, leeches and a permanent sense of awe accompanied us as we spent five days learning research skills in the forest, from baiting dung beetles to mist-netting and investigating the extent of insect herbivory. These were put into practice whilst designing and conducting group research projects on the relationship between avian morphology and ecology, the effectiveness of camera traps for large mammal surveys, *Odonata morphospecies* across habitat types and more, working closely with and learning from our supervisors. We witnessed the slow, ponderous movement of orangutans through the canopy, the wailing call of the gibbons at dawn and the dark grey shadows of elephants travelling beside the tracks.

Immersed in the forest like this, it was easy to forget the scale of deforestation, but this was brought sharply back into focus by a day visiting the long-term biodiversity experiment, where the impact of logging and the value of the ecosystem services provided by regenerating secondary forests are being experimentally assessed. The complexities of the oil palm industry – so often portrayed in black and white – were also introduced to us in lectures and reinforced on a visit to a smallholder oil palm plantation, where we passed round an innocuous oil palm fruit in the blazing sun.

Rather than focusing on environmental catastrophe, studying with researchers actively involved in tropical forest conservation inspired feelings of positivity and deepened our understanding of how we can work towards positive environmental change.

Student group standing between dipterocarp buttress roots

Orielton

Mavis Teo
St Catz

I must admit I had not been looking forward to a trip to rural Wales in the middle of term, a month or so before our prelims. However, the seven days that we did spend in Pembrokeshire ended up being one of the most valuable experiences of first year.

We can sit in a lecture theatre and listen to the lecturer talk about blue tits all day, or poke at arthropods in the teaching labs, but it's hard to get a proper sense of field ecology without being out in the field. There is nothing like stalking an elusive birdcall through the woods, stumbling over tree roots and peering into the foliage until—finally—the speckled underbelly of a cuckoo is spotted. Turns out they really do sound like their namesake.

You learn what it feels like to stick your hand into freezing cold rock pools to sort through bits of seaweed. You learn how to really look out for the ligules of grasses—that little membranous flap at the junction of the sheath and blade. You stand as still as possible in the dark, waiting for bats to exit their roost. You use R with real data for the first time—the P values are dismal but it's still a revelation.

The field course is also a fantastic opportunity to get to know your peers from other colleges. It turns out that trekking through brambles and squinting at Dipterans under microscopes really does bond people. Everyone there—support staff and demonstrators alike—was exceptionally kind and helpful, no mean feat in the face of over a hundred eager undergrads.

The main takeaway from Orielton is an obvious one, and I think best said by Darwin himself: "from so simple a beginning endless forms most beautiful and most wonderful have been, and are being, evolved." This is the natural world. Go experience it for yourself.

Dragonfly morphospecies

Smallholder oil palm plantation

Insect herbivory visible at dawn

Cross section of an oil palm fruit

DPhil Student Projects

Benjamin Van Doren

Somerville College

Change and flexibility in avian migration

Bird migration has intrigued people for millennia, but there is a lot we still don't understand about migratory birds and their responses to a changing world. On short time scales, birds' decisions are closely tied to weather patterns, like winds, rain, and temperature. But migration is also governed by hard-wired instinct, with aspects of its timing and direction seemingly coded into birds' very DNA. Using data from lab experiments, tracking devices, citizen scientists, and even Doppler radar, I study the interaction of these internal and external factors across scales. One aspect of my research centers on the Blackcap, a songbird that has recently begun spending the winter in Britain instead of Iberia and Africa due to milder winters and an abundance of garden bird food. Is the change in migration we see in the Blackcap a sign of things to come?

Divya Sridhar

Merton College

Understanding the role of MBD2/3 in regulating stem cell fate in the planarian Schmidtea mediterranea *using functional genomics*

Planarians have remarkable regenerative capacity owing to the abundance of pluripotent adult stem cells. They can regenerate any region of their body including the brain in 7 days. Moreover, multiple tissue pieces cut from a single animal will each go on to regenerate new bodies. The regulation of the regenerative programme in flatworms at the transcriptional level is well documented but the epigenetic regulation of stem cell function is unclear. My research aims to understand the function of histone modification and nucleosome remodelling complexes in stem cell maintenance and differentiation. I am currently using and developing techniques such as RNA-, ChIP- and ATAC-seq to assess the function of conserved epigenetic regulators (including MBD2/3). We hope to better understand the histone modification-mediated regulation of stem cell function and differentiation in planarians.

Lovemore Sibanda

Lady Margaret Hall College

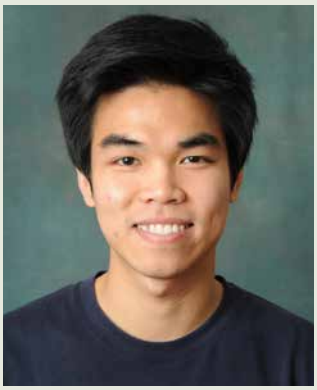
Old wine in new bottles: Evaluating the impact of the Long Shields Community Guardian program, a non-lethal human-lion conflict intervention in north-western Zimbabwe

Conflict with humans over livestock depredation is a primary threat to wild lion populations in Africa and sustainable coexistence has not been achieved. This doctoral study seeks to evaluate the impact of the Long Shields Lion Guardians programme; a traditional non-lethal human-lion conflict intervention that we refined and reintroduced to rural communities living on the periphery of Hwange and Zambezi NP, north-western Zimbabwe. In this study, we explore if the Long Shields Lion Guardian programme was effective in mitigating conflict between humans and lions and if attitudes of subsistence farmers toward lions improved as result of the Long Shields Lion Guardian program. This research will contribute towards lion conservation strategies in the region and inform decision-making.

Anke Kloock
Christ Church

Microbe-mediated protection in experimental evolution with Caenorhabditis elegans

Bacteria are ubiquitous colonisers of animals. However, only recently, have we begun to understand their importance in different host biological processes. While bacteria can cause serious disease, many help their hosts in many different, and not yet fully understood ways. To further explore the diversity of interactions with microbes, I used an animal host (a nematode worm, *Caenorhabditis elegans*) and their good and bad bacteria. In lab experiments, I coevolved the worm host with a bacterial strain (*Enterococcus faecalis*) that protects against infection by a pathogen (*Staphylococcus aureus*). This interaction has helped me to discover that bacteria-mediated protection needs pathogen pressure to evolve, even though the pathogen does not need to be present all times.



Nattapong Sanguankiattichai
St Catz

Investigating the production of an inhibitor of plant B-galactosidase by Pseudomonas syringae

Plants are continuously challenged by microbial pathogens, which have a significant impact on crop production. During infection, pathogenic bacteria use various strategies to manipulate host plants and suppress immunity. My project investigates a mechanism whereby bacteria produce an inhibitor of a plant defence-related enzyme that plays a role in the early detection of pathogen invasion. I aim to characterise the identity and biosynthesis of this molecule as well as the regulation and evolution of the virulence mechanism in the bacteria. This research will contribute to increasing knowledge of plant-pathogen interactions that can improve ways of combatting plant diseases.

Rona Costello
Linacre College

Charting the evolution of the plant organellar proteome

The functioning of plant cell organelles, such as the chloroplast and mitochondrion, depends upon the translocation of specific proteins from the cytosol of the cell into each organelle. My research aims to elucidate how this set of proteins, known as the 'organellar proteome', has changed during the evolution of different plant groups. So far this has involved using computational and phylogenetic approaches to reconstruct when changes in protein subcellular-localisation have occurred during evolution of around 40 plant species. As well as contributing to our understanding of organelle evolution, I hope to use this work to identify novel proteins that were recruited to or from organelles during the evolution of C4 photosynthesis.

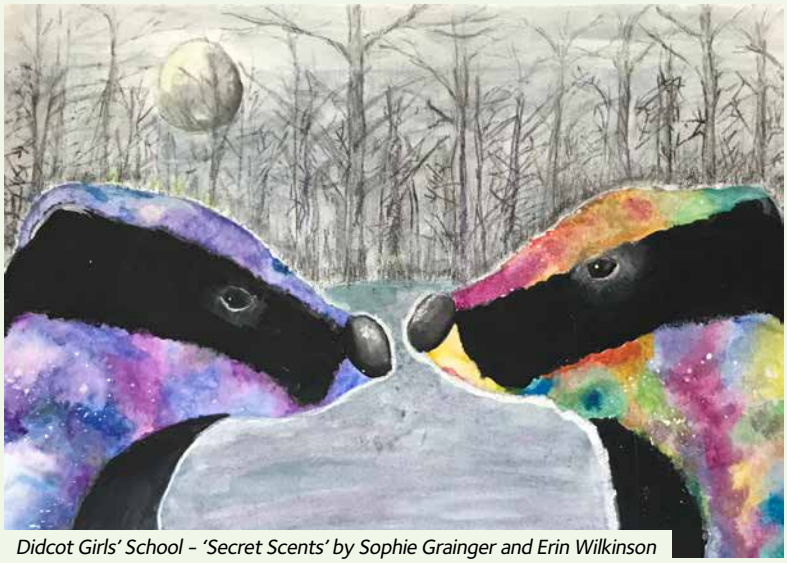
Beatriz Moreno Garcia
University College

Engineering photosynthesis for increased crop productivity

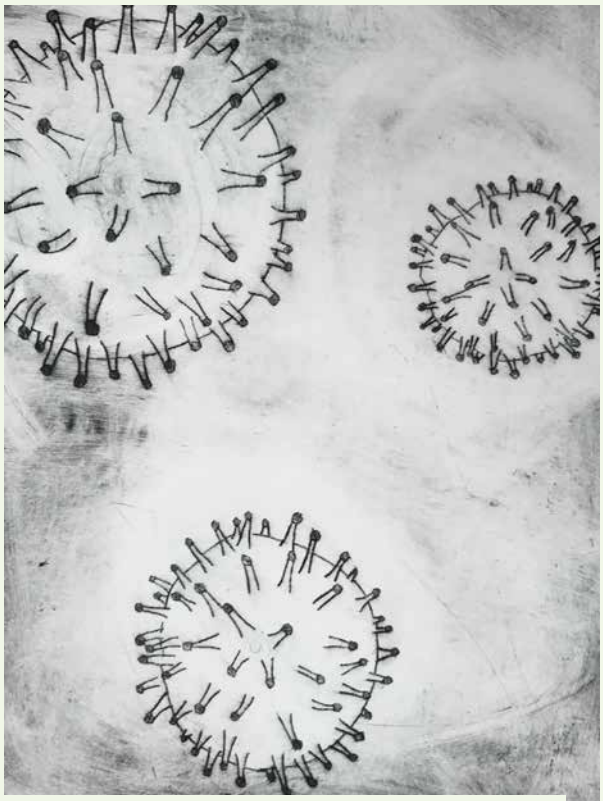
With global population predicted to reach 9 billion people by 2050, food security represents one of the most pressing issues of the 21st Century. The use of plant biotechnology can contribute towards an increased food availability by increasing crop productivity. My DPhil project aims to optimise photosynthetic efficiency by exploring combinatorial transgenic interventions in leaf carbon metabolism. Using *Nicotiana tabacum* as a model species, I have generated plants that carry different combinations of promising transgene targets. These genes are involved in photosynthesis, sucrose synthesis, and sucrose export. Their combined overexpression could lead to significant improvements in plant productivity.

Local schools' art outreach

We are delighted to be the recipients of some exceptional new artworks, now hung with pride across our Department buildings. Firstly, 'Beyond Boundaries' was a project led by the University that encouraged young Oxfordshire state school students to create artwork inspired by research from Black, Asian and Minority Ethnic scientists and mathematicians. We received two wonderful works titled 'Bacteria' and 'Secret Scents', inspired by the work of Vinoy Ramachandran and Tanesha Allen, respectively.



Didcot Girls' School – 'Secret Scents' by Sophie Grainger and Erin Wilkinson



Oxford Spires School – 'Bacteria' by Mathilda Percy-Bowersox

Secondly, we invited art students from Cheney, St Edward's and Magdalen College to produce artwork inspired by the research themes across biology, and we were simply blown away by the work produced by these schools. With special thanks to Chris Otley for his help in coordinating this programme!

Magdalen College School – 'E. coli' by Tahmid Azan, Joey Chataway and Gabriel Esteban

St Edward's School – 'Bees' by Cleo Bates, Alanna McCrum, Tom Magnusson

Cheney School – 'Coral: beautiful disaster' by Ruby Sherrington Smith

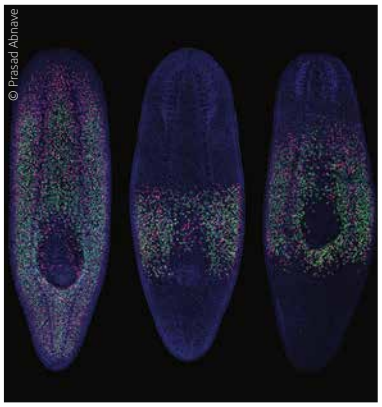
Looking to the future of Biology

Although the closure of the Tinbergen Building was a crisis for the Zoology Department, it also provided a wonderful opportunity to develop biology in Oxford, and that is something we have capitalised on. For example, in October 2019, the Plant Sciences and Zoology Departments will start teaching the new four-year Biology course, and by 2024 the two departments will have joined together to form a new biology department that will be housed, along with Experimental Psychology, in the new Centre for Life and Mind that will replace the Tinbergen Building.

As part of this exciting revitalisation of biology in Oxford we have begun exploring fundraising and partnership opportunities to ensure the subject thrives in Oxford over the coming decades. As well as fundraising for the new building, we seek support for undergraduate field courses, funding for graduate scholarships to ensure the brightest and best students can take up their place at Oxford, investment in research projects, and endowment for key academic positions. We would welcome your advice, ideas and suggestions about our ambitious plans, and we will also be holding a number of events in the future to which all alumni and friends will be welcome.

Professor Tim Coulson
Associate Head of Department of Zoology

If you are interested in learning more please contact Tim Coulson (Tim.Coulson@zoo.ox.ac.uk or 01865 271241) who is the academic lead on fundraising and external relations.



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