Biology News

Issue Two | 2013
www.biology.ox.ac.uk

UNIVERSITY OF OXFORD

Department of Plant Sciences
Department of Zoology

Liam Dolan Head of Plant Sciences Department

Plant Science (Botany, Agriculture and Forestry) is undergoing a quiet revolution. There is growing recognition of the central importance of plants in the production of food and the inherent value of plant diversity for the health of the planet.

John Baker

The public appreciation of the importance of plant science stems in part from the food commodity price spikes of 2008 and their subsequent upward trajectory. Furthermore the world population will increase by approximately 2 billion to 9 billion by 2050 and there is a consensus that food production will have to increase. Previously yield increases were driven by the availability of cheap fertilisers with often catastrophic impacts on ecosystems. This approach is no longer an option. We need to be creative. Plants that produce more yield from less fertiliser and water without causing ecosystem catastrophe are needed.

The pivotal position of plant sciences has been recognised by organisations such as the Bill and Melinda Gates Foundation which funds two research projects in the Department. Jane Langdale and Steve Kelly are part of a global network of scientists who are engineering rice to increase its photosynthetic capacity. Cassava on the other hand is the food of the poorest of Africa and has enormous potential to contribute to the calorific intake of people on low incomes. The Gates Foundation is also funding Steve to understand the infection of cassava by a trypanosome parasite of this crop.

The tension between food production and conservation of biodiversity is to be seen in many parts of the world. Andy Hector, a new professor joining the Department from the University of Zürich, is pioneering approaches to optimise food production and biodiversity conservation in dipterocarp forests in Borneo. Lindsay Turnbull, another new appointment who will take up a University Lectureship and Tutorial Fellowship at The Queen's College, will investigate how genetic mixtures of crops can enhance yield. These research programs demonstrate how diversity and food production need not necessarily be mutually exclusive and may in fact act in synergy.

The recognition of the importance of plants in these global challenges has not been missed by Oxford undergraduates. The second year Plants and People course teaches plant science from the crop's point of view. Furthermore the Soils Food and Food Security course is proving to be immensely popular with almost 50% of third year students taking the course. This recent upsurge in interest is reflected in an increase in charitable giving to DPhil scholarships in the area of crops and food security. This enables Oxford to play its part in rising to the challenges of the next 30 years.

These undergraduates and postgraduates will change the world by developing cultivars, technologies and discoveries that will help to feed 9 billion without devastating the planet that we call home. It is a very exciting time to be a plant scientist.

Graduate student projects

Keeping species apart

Owen Osborne (Queen's)

John Baker

What are the genomic changes that underlie evolutionary processes such as speciation and adaptation? My research addresses these questions in two species of ragwort found on Mount Etna. These species have recently diverged from a common ancestor and are under on-going selection that maintains their integrity in the face of ongoing hybridisation. I use computational techniques to detect 'molecular signatures' of evolutionary processes in the genomes of these species and then link these 'signatures' to ecological and morphological diversification. This is providing insights into how evolution works at the fundamental level of the hereditary material itself, and how this relates to morphological and physiological adaptation.

Getting to the root of evolution

Thomas Tam (Christ Church)

John Baker

Water and nutrients are absorbed by root hairs that form at the interface between the plant and the soil, making this cell type a promising target for crop improvement. My research aims to discover the gene network responsible for building root hairs. I discovered that key components of this gene network are found in all groups of land plants (even in mosses!), where they perform similar rooting functions. This indicates that the mechanisms controlling the development of cells at the plant-soil interface are ancient. By tracing the evolution of a gene network, I aim to discover fundamental genetic mechanism have brought about morphological and physiological changes in plants over the past 500 million years.

Discovering plant species

Zoë Goodwin (Wolfson)

Chris Jeffree

Our ability to understand, measure and evaluate the extent of the current 'biodiversity crisis' is hampered by our lack of knowledge of how many species there are on Earth. Even for relatively well-known groups such as the flowering plants, the inventory of all species is yet to be completed. I am analysing the process of species discovery to develop a novel approach to rapidly revise large groups of poorly known plants which contain the majority of species that remain to be discovered. I am using this 'Foundation Monograph' approach and the large pantropical genus *Drypetes* as my model.

Peter Holland Head of Zoology Department

Welcome to Issue 2 of the newsletter about Biology at Oxford, bringing you news from the Departments of Zoology and Plant Sciences. In this issue we showcase selected research highlights, tell you about some improvements to our facilities, and provide a glimpse of a few research projects undertaken by our undergraduate and graduate students.

In the Department of Zoology, we have appointed several new academic staff. In September 2012, Aziz Aboobaker arrived with his research team working on genomics, development and regeneration in flatworms; in January 2013, distinguished evolutionary ecologist Tim Coulson joined the Department and Kayla King who has research interests in the evolution of parasitism will join us later in 2013. Dora Biro and Ashleigh Griffin will join us as University Lecturers in Animal Behaviour and Evolutionary Biology respectively, and Pat Nuttall has joined us as Professor of Arbovirology. The department has long focussed on supporting early career research fellows, and into this growing fold this year we have been fortunate to recruit (amongst others) William Durham, Stuart Wigby, Bridget Penman, Laura Ross and Jarrod Hadfield. Tobias Uller, well known to recent undergraduates through the animal diversity practical course, has become one of the eleven holders of

Amanda Holland

prestigious Royal Society University Research Fellowships in the Department.

I must mention the retirements of Sarah Randolph and David Rogers, who have each given an impressive four decades to Zoology in Oxford. Both Sarah and David have made important contributions in the fields of spatial ecology, vector biology and entomology; they have each influenced literally thousands of students (including me!)

In October 2012 our new intake of UK undergraduates were the first to be charged the increased tuition fee. This has been a topic of much debate inside and outside the University, but it is important to note that increased fees simply replace what has been removed by cuts in government spending on Higher Education. It is also worth remembering that Oxford has one of the most extensive bursary schemes of any UK University. We know that students today, perhaps more than ever, expect a very high quality education and superb facilities. We are confident that the Biological Sciences course already offers this, and in 2012 we improved facilities even further by building an impressive new IT suite for teaching quantitative biology and data analysis.

I am always delighted when our academic staff and students win prestigious awards for their research, and this year has been no exception. A few examples include the Marie Curie Prize for Promising Research Talent to Gkikas Magiorkinis, the Institute of Ecology and Environmental Management Medal to Bob May, the Royal Geographical Society Back Award to Simon Hay, the UFAW Medal for Outstanding Contributions to Animal Welfare Science to Marian Dawkins and the George Stephenson Award to Nathan Phillips. In October we also received the momentous news that the 2012 Nobel Prize for Physiology or Medicine had been awarded to Sir John Gurdon for research that was undertaken in the Department of Zoology in Oxford in the 1960s.

Graduate student projects

Malaria vectors

Danica Fabrigar (Jesus)

Andrew Hammond

With the support of the Sir Richard Southwood DPhil Scholarship, I am able to pursue research on the population structure of African malaria vectors. One issue concerns whether the long-term indoor use of insecticides and bed nets is generating an evolutionary selective pressure favouring outdoor, rather than indoor, biting behaviour. I have been collecting mosquito samples in the Gambia and will be using next generation DNA sequencing technologies to test for evidence of selection. Identifying such changes will be crucial to successful malaria control.

Asymmetry in animals

Nathan Kenny (St Cross)

Erica Namigai

Left/right asymmetries – such as the positioning of the liver predominantly on the right of humans – are found across the animal tree of life. Only recently has it been suggested that these asymmetries are patterned by similar genes in organisms as diverse as snails, mice and sea urchins. With the help of a Clarendon Studentship, my work has focused on comparing the underlying mechanisms controlling the establishment and maintenance of asymmetry in diverse animals. I am using genome sequencing and analysis of gene activity in embryos of limpets and worms to get new insights into how asymmetry is controlled, and how it evolved.

Beehive fences

Lucy King (Balliol)

Save the Elephants

How can farmers prevent African elephants raiding their crops? It is a tough problem, because elephants do not respect fences and can rapidly destroy an entire crop. My research as a DPhil student in Zoology showed that elephants can be deterred by the sound of honeybees, and furthermore that 'Beehive Fences' can be built incorporating live beehives at regular intervals to protect small farms. I am now working with the charity Save the Elephants, and in partnership with *Disney Worldwide Conservation Fund*, to roll Beehive Fences out across several African countries for the benefit of elephants and farmers. My DPhil work was awarded the *UNEP/CMS Thesis Award* by the United Nations, and in 2013 I won the Future for Nature Award.

Field course news

Oxford Biology undergraduates and teaching staff met the Duke and Duchess of Cambridge during last September's Tropical Forest Ecology field course in Borneo. Prince William and Katherine were visiting Sabah as part of their Diamond Jubilee tour of South East Asia and the South Pacific. After a helicopter flight over the largest remaining areas of primary forest on the island, the Royal couple spent the morning at the Danum Valley field station meeting local and visiting scientists and students, and learning about the research underway there. Following a short trek in the forest and a climb into the rainforest canopy, they visited the field station's teaching laboratory and chatted to Oxford students and staff about the field course and rainforest conservation.

Owen Lewis

Samson Lawrence, Yayasan Sabah group

The Duke and Duchess of Cambridge at Danum Valley field station, Sabah

The Elton Room

Peter Holland

The new Elton Room

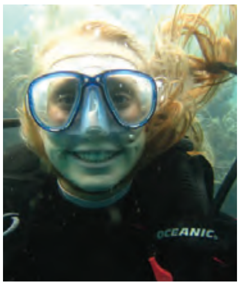
The space in the Department of Zoology that housed the library collections of Charles Elton, one of the founders of ecology, has a new use. The books, journals and reprints have been moved to the Radcliffe Science Library, as part of a re-structuring of Oxford libraries, giving an opportunity to update further the teaching facilities for Biological Sciences. The newly refurbished 'Elton Room', officially opened on the 2012 Alumni Day, now accommodates a state-of-the-art computer suite for teaching quantitative biology. Individual desks with client terminals for 56 students permit class teaching, plus a facility is provided for individual study and research. Starting with 'Quantitative Methods' in the first year and continuing on to a wide range of advanced second and third year modules, the new teaching suite will enable students to develop their skills for interrogating large data sets – ranging from whole genome sequences, to images from microscopy or satellites, to ecological meta-data. Purchase of the computer equipment, an interactive lectern and three simultaneous projectors was made possible by a generous donation from the E. P. Abraham Cephalosporin Fund.

Rosalind Harding

Undergraduate student projects

The cleaner fish market

Laura Voak (New)



Kristen Nehr

Two months, 60 dives and 2 underwater cameras into my project, I was still in awe of my subject – *Labroides dimidiatus*, the bluestreak cleaner wrasse – running a business. The cleaner fish mutualism is analogous to a human economic market, with 'clients' queuing at cleaning stations to be serviced. I travelled to Indonesia to film thousands of interactions and analyse why some client species were given a higher quality service than others. Remarkably, transient species (whose home range included >1 cleaning station) received the highest quality service and were even allowed to jump the queue, together with piscivorous species which posed a threat to the cleaner. Queues were also much longer at sunrise (when the cleaners begin their day) and in more polluted locations.

Senescence in a potential model organism

Lauren Sumner-Rooney (St Anne's)

Peter Ward

I investigated the effects of vitamin B12 on senescence in the fish *Nothobranchius furzeri*, which was proposed as a new model organism for ageing studies. To detect age-associated changes, I video-tracked subjects' motor activity, and tested their ability to solve a maze, at both young and advanced ages. I found that the B12-deficient subjects were initially much less active than the controls, but that this reversed as ageing progressed. The autonomy granted by having my own project was a rewarding experience, and gave me a valuable insight into the exciting world of scientific research, inspiring me to begin a PhD.

Malaria vaccines

Katrina Spensley (St Catherine's)

Society of Biology

Malaria vaccine design is complicated by parasite protein sequence variability. The project explored the possibility of finding immune selection signatures using computer analysis of publicly-available *Pf*AMA-1 protein sequence data instead of established laboratory methods. New programs had to be written to handle the volumes of data involved, and positive results suggest that this approach is viable. For me, the project was a fascinating glimpse into leading-edge scientific research. My project was awarded the ZSL Charles Darwin Award and Marsh Prize from the Zoological Society of London, and I was shortlisted for a SET award for the work.

Undergraduate student projects

One of the undoubted highlights of Biological Sciences at Oxford is the Honours Project (also known as a dissertation in the outside world). Every student does one and most find it both fun and intellectually challenging. Most members of academic staff in Plant Sciences and Zoology are keen to supervise at least one or two students per year, and undergraduates either join an existing research group as a team member, or carry out their project on their own but with the advice of a member of academic staff. The practical work for the Honours Project can be carried out in the labs, fields, rivers or woods of Oxford, or students can choose to visit other institutions and organisations within the UK, or indeed further afield in Europe or the rest of the world. Here coral reefs, rainforests and even the deepsea can provide habitats to investigate. Choosing the topic for a research project is not trivial to say the least. All academic staff provide details of their research allowing students to gain a good idea of what may be available, so any subject within the hugely broad spectrum of interests across both Departments (and sometimes in the wider university) is potentially a possibility. This amounts to pretty much the whole of biological sciences! Students normally do their practical work in the Trinity Term of their second year, but those leaving Oxford often use part of their summer vacation as well, as long as they are able to raise the funds for travel and subsistence. Both Departments run small bursary schemes to help support some student travel, primarily funded by donations made by former academic staff and students. As with all research, success (measured in terms of new, significant results) cannot be guaranteed, and the experience is just as much about learning the process of planning and conducting scientific research, and analysing data.

Some projects are phenomenally successful, however, resulting in peer-reviewed scientific papers that make a real contribution to knowledge and stand the test of time. This year for example, Katrina Spensley's project on malaria proteins was judged one of the best three student biology projects across Europe in the Science, Engineering and Technology Student of the Year Awards. One day, if the Biological Sciences degree at Oxford is extended to a fourth year, even more emphasis will be placed on the Honours Project; for now, it is an undergraduate's first real chance to see what research is like, and for many, to decide if this is the career they've been looking for.

Martin Speight

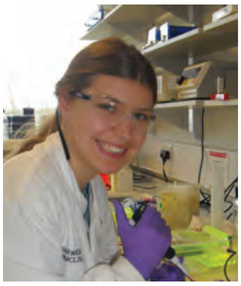
Martin Speight

Pitfall trap and temperature/humidity data logger on a student project on insects in meadows, Oxfordshire

Undergraduate student projects

Immune response in plants

Mary Tetlow (Brasenose)



Ana Mendes

My research project was carried out during the Summer of 2011 in collaboration with the University of Warwick, under the joint supervision of Professor Sarah Gurr in Oxford and Professor Jim Beynon in Warwick. I investigated the role of three genes potentially key to the immune response of *Arabidopsis thaliana* using microarray analysis. This identified interesting roles in the coordination of immunity for two of these genes. Future research will define the precise molecular function of these genes. Working in the lab gave me insight into how discoveries are made and I have also gained valuable experience in a wealth of molecular techniques.

Bird malaria

Philip Birget (St Peter's)

Linda Nell'Angela

My Honours project considered the influence of natural disease occurrence (malaria) on the size of the badge of male house sparrows. I also integrated a measure of testosterone exposure (bird digit ratios) during the egg stage to control for potential maternal effects. This work was carried out in two regions, an insecticide treated region and a region with no mosquito control. The main result was that birds with bigger digit ratios were more likely to be infected, but more molecular work with Oxford researchers is required to confirm that finding.

Space use by snakes

Tom Williams (St Anne's)

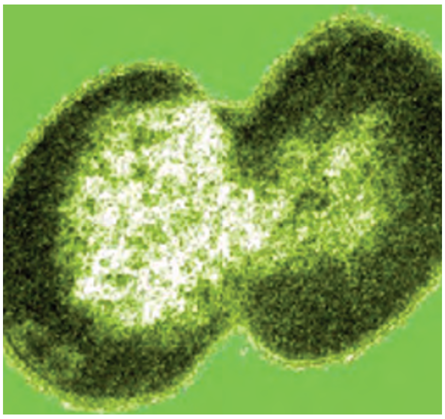
Ben Evans

In July 2012, I travelled to a dry forest in North-western Madagascar in order to study two species of Malagasy hognose snakes (*Leioheterodon*). These snakes are unusual in both the ecology and physiology. I spent two months in the field individually marking animals, monitoring individual movements and species occurrences. I then used this data to examine the effects of both intraspecific and interspecific competition on space use, using ArcGIS, occupancy modelling and randomisation methods. I was able to statistically demonstrate the second ever example of territoriality in snakes, and this suggests territoriality is more widespread in snakes than previously thought.

Evolution, ecology, organismal biology and bacterial pathogens of humans

Since 1997 my group has been working in the Department on the evolution of genetic diversity in bacterial pathogens and its consequences for human health, concentrating on *Neisseria meningitides* (the meningococcus, a global cause of meningitis and septicaemia) and *Campylobcter jejuni* and *Campylobacter coli*, collectively the most important causes of bacterial gastroenteritis.

At first glance, a group studying bacterial diseases of humans in a Zoology Department seems incongruous, but the non-medical approach that we take to studying human disease makes the Department a very suitable home, and one in which we have thrived. Rather than taking the diseased patient as the starting point for our studies, our first questions about the pathogens we study are founded in organismal biology, ecology and, above all, evolution: what is the lifestyle of the bacterium in question, how has this evolved and what is the role of human pathogenesis in these processes? By addressing these questions, we aim to obtain insights into how the burden of the human disease cause can be reduced. For both organisms we have taken a multidisciplinary approach, collaborating with other members of the department and including high-throughput genomic techniques.



Andrew Hammond

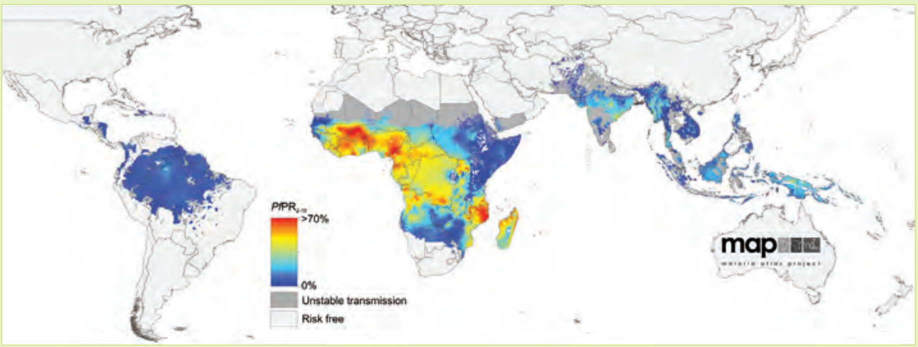
The meningococcus – an electron micrograph of an accidental killer

The meningococcus has a fearsome reputation as a highly aggressive pathogen which can kill children in hours; however, examination of its evolution and ecology reveals a very different story. A large proportion of people, especially young adults (and particularly undergraduates!) carry the meningococcus harmlessly in their throats and disease, when it does occur, is an accident that is as bad for the bacterium as it is for the human host as disease is ends host-to-host transmission. Intriguingly, meningococci are highly diverse and paradoxically some persistent strains are very much more invasive (likely to cause disease) than others. Our experimental work, combined with theoretical studies conducted in collaboration with Sunetra Gupta, is providing explanations for this and has led to a vaccination approach currently in phase I trials in collaboration with Andrew Pollard in Paediatrics.

Although the most likely reason for someone in the UK having bacterial gastroenteritis in the UK, *Campylobacter* infection of humans is also incidental and accidental. With genetic characterisation studies of *Campylobacter* isolates from a range of sources, including human disease from the John Radcliffe Hospital, we have helped to establish that retail poultry meat is a major cause of human disease. Working with Marian Dawkins and the Food Animal Initiative in Wytham we have uncovered possible links between animal welfare and infection with *Campylobacter* that may help reduce the burden of this unpleasant and costly human disease. Collaboration with Andy Gosler in the EGI also helped to indicate that wild birds are not a likely source of *Campylobacter* infection for humans (or, indeed, chickens).

Martin Maiden

Infectious disease epidemiology mapping



Catherine Moyes

Estimated global distribution of Plasmodium falciparum *malaria endemicity in 2010*

Nearly 1500 pathogens have been recorded 'making a living' on or in humans, and together they cause ~350 infectious diseases recognised by physicians. Many of these infectious diseases have a ubiquitous global presence in human populations, albeit at very different prevalence levels. Researchers in the Department of Zoology identified a list of 174 diseases with more limited geographical spread, for which there is a good public health rationale to make accurate distribution and risk maps. Alarmingly, so far only 3% of these (7 diseases) have satisfactory maps produced.

This leaves a considerable blind spot in international biosurveillance. It also presents an obstacle for those wishing to measure the health impact of infectious diseases. Perhaps most worryingly, it also impairs our ability to infer what might happen to the infectious disease landscape under the many forces of environmental change.

With the support of the Wellcome Trust, Simon Hay and colleagues have spent much of the last decade mapping in detail the worldwide distribution of malaria (see www.map.ox.ac.uk), still one of the biggest infectious disease killers of children globally. These data are now being used by agencies in many countries to help in critical decision making, for example in deciding where limited public health resources should be spent.

Trees for tomorrow

Kevin Tuck

Ash copse

The arrival of ash dieback in the UK, along with the recent emergence of diseases such as horse chestnut bleeding canker, acute oak decline, *Phytophthora ramorum* in larch, and *Dothistroma* (red band) needle blight in pine, has brought new attention to the challenges facing plant pathologists world-wide. Trade and traffic in plants and plant products are enabling pathogens (disease-causing microorganisms) to move from country to country with unprecedented speed. As a nation that is passionate about plants and gardening, we take pleasure in bringing plants from around the world into our gardens and homes, but a single shipment can carry a lethal legacy for native plants.

Genome sequence analysis of multiple strains of the pathogen *Pseudomonas syringae* pv. aesculi, the causal agent of horse chestnut bleeding canker, has shown that all the strains isolated from infected trees across the UK are nearly identical, suggesting that they originate from a single, recent introduction. New disease outbreaks have also arisen from changes in the behaviour of existing pathogens. *Phytophthora ramorum* was originally reported in the UK in 2002 in plants and shrubs such as rhododendron, viburnum and camellia, but in 2009 emerged as a lethal pathogen of Japanese larch trees (*Larix kaempferi*), the first time it had been reported as pathogen of an economically important conifer.

In a world focused on short term impact, tree diseases illustrate the need to take a long term view. Plants, unlike humans, lack adaptive immunity, the ability to dynamically modify their immune system to recognise and resist new pathogens. Instead, they possess innate immunity, a form of disease resistance in which years of natural selection have driven the evolution of surveillance systems that recognise and respond to commonly encountered pathogens. As a result, native plants often have little or no ability to resist exotic pathogens. In trees this problem is particularly acute, for while arable farmers can select and sow a new cereal variety each year, trees can only play the genetic hand they have been dealt. One of the major challenges facing plant pathologists is the challenge of identifying or breeding trees and crops with durable resistance, which can endure in the face of successive waves of pathogen attack.

In my own research group we are currently trying to understand how and why disease resistance breaks down, and how pathogens acquire the ability to infect previously resistant plants. This may help us to assess whether plant varieties and species that are currently resistant to pathogens are likely to retain this resistance in the future. We have also been studying how environmental factors such as soil nutrients can tip the balance between infection and immunity. Researchers have speculated that climate change, extreme weather, and other environmental changes associated with agriculture, industry and development have opened the door to new diseases by reducing the ability of trees to resist infection, but further research is needed to assess these possibilities.

In the case of ash dieback, we are fortunate that ash exhibits a high degree of genetic diversity, and that trees have already been identified that appear to be resistant to the disease, providing optimism that durably resistant lines can be found or bred, and that some mature trees will survive the current outbreak. The University of Oxford is likely to make an important contribution to this research due to the work of local researchers such as David Boshier in analysing the genetic diversity, reproductive biology and local adaptation of ash in Britain and Europe together with partners across the EU.

So, although the newspaper headlines are in many respects justifiably bleak, the horizon holds some hope. Detailed understanding of the biology of these pathogens and the trees they infect, along with better management practices, disease resistant plants, increasingly sensitive disease detection methods and better import control measures may all help to ensure we do have trees for tomorrow.

Gail Preston

Gail Preston

Bleeding symptoms on horse chestnut

A challenge for the next decade is to streamline methods and scale-up this work, to consider a much broader suite of infectious disease pathogens of public health significance: all 174 of them.

One strategy, which has a great heritage in epidemiology, is to exploit advances in ecology, particularly developments in 'species niche modelling', allowing prediction when data are scarce. A second method is to collaborate with computer scientists developing systems to extract information on infectious diseases from the deluge of digital information on the internet. We hope this mix of ecology and informatics will help us rise to these Big Data challenges in mapping and make significant in-roads into the spatial epidemiology of infectious disease.

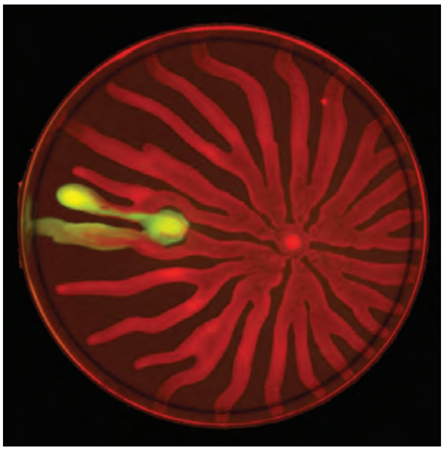
Simon Hay

Cooperation and conflict: from bee-eaters to bacteria

Erik Svensson

White-fronted bee eaters

Kevin Foster



Social interactions between bacteria in a petridish

The interactions between organisms can lie anywhere on a continuum from extreme conflict to peaceful cooperation. At the extreme end, males of some insects have huge jaws that they use to chop off each others heads in competition for females. At the peaceful end, natural history documentaries have made famous how meerkats live in cooperative groups, where members babysit and feed pups that are not their own. Several research groups at Oxford are trying to make sense of this variation, as well testing how social behaviours can be harnessed to help us control pathogens.

Some birds and mammals live in cooperative groups such as bee eaters, where individuals care for young that are not their own. One example is the meerkats mentioned above, but another from the UK is the family groups of long-tailed tits that move noisily between trees. However, many birds and mammals do not live in cooperative groups. For example, all the other non-human birds and mammals in the UK! How can we explain this variation?

Ashleigh Griffin and her collaborators found that a major factor was the sex life of females. If females are promiscuous, the chicks in her nest will be half-siblings with the same mother but different fathers. If she is monogamous, the chicks in her nest will have the same father and be full siblings. Helping full siblings to breed is twice as effective as helping half siblings at transmitting genes to future generations, and so cooperation is more likely to evolve in species where females are relatively monogamous, such as meerkats and long-tailed tits.

Cooperation isn't the preserve of higher animals. Over the last 20 years it has been found that bacteria engage in a range of cooperative behaviours. For example, bacteria use secretions to help them to move around as a collective group. Kevin Foster and his collaborators showed that while these secretions improve the fitness of all of the bacteria, strains that do not produce the secretion can also make use the secretions made by other, more cooperative, cells. What then prevents the lazy non-producers from taking over? It turns out that the cooperators only produce the secretions when they have more resources than they need to grow. This prudent behaviour allows them to compete well against strains that do not invest in the cooperative good and helps to explain how cooperation can be stable over evolutionary time.

Our understanding of social behaviours can also be put to applied use. Bacterial pathogens appear to rely on cooperative behaviours to grow and hence damage their hosts. For example, they release a range of molecules that act as toxins, scavenge nutrients and break down host tissue. Furthermore, bacteria signal to each other to coordinate these behaviours, only switching them on when they have reached sufficient density to swamp their hosts.

Consequently, if we can learn to manipulate cooperative behaviours, then this could provide a tool for helping us reduce the virulence and even eliminate infections. Stuart West and collaborators found that if you add non-cooperative 'cheats' to a bacterial infection that this reduces the rate at which bacteria grow and more than halves the death rate in hosts. We are currently investigating the extent to which this could be exploited clinically.

Stu West

Nobel Prize for Oxford research

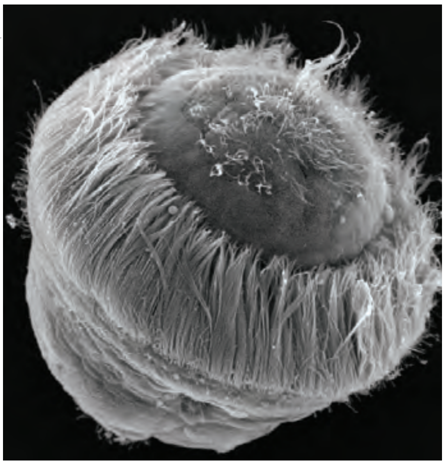
Everyone connected with biology in Oxford was delighted to hear the news that Sir John Gurdon had been awarded the Nobel Prize in Physiology or Medicine for 2012. John was a undergraduate and graduate student in the Department of Zoology, Oxford, and then an Assistant Lecturer, before moving to Cambridge in 1972. John shares the prize with Shinya Yamanaka from Kyoto, 'for the discovery that mature cells can be reprogrammed to become pluripotent'. The Nobel Prize recognized John's work on cloning in *Xenopus* (clawed toads) conducted in Oxford in the 1960s. John Gurdon's experiments demonstrated that cells do not lose genes as they become specialised, thereby opening the way to stem cell research and potential therapies using cellular reprogramming.

Using genomes to study animal diversity and evolution

Genome sequencing is playing an increasing role in many areas of our research, enabling new projects and allowing previously intractable questions to be tackled

So pervasive is 'genome biology' that it is easy to forget that it is only a little over a decade ago that the sequence of the human genome was first revealed. Until recently the massive cost of such projects kept them the preserve of giant international consortia, focussed on model species such as mouse and fruit fly. However, new inexpensive and efficient DNA sequencing technologies mean that genome biology now penetrates many areas of research. Twenty years ago, a single researcher might spend a year to obtain a few thousand nucleotides of DNA sequence, but today it is straightforward to determine tens of billions of nucleotides in a few months. It is even possible for a single postgraduate student to sequence the complete genome of their 'own' study organisms, whatever they may be. In the Department of Zoology, many researchers are using genome sequencing to investigate topics including animal phylogeny, the origin of particular sets of genes, the embryonic development of neglected groups of organisms, mechanisms of mutation and the effect of the environment on evolution and development.

Helen Thompson



Peter Holland

David Ferrier

Kyle Martin

Some species for which Department of Zoology researchers have recently determined genome sequences. Clockwise from top left: *larva of the common limpet, comma butterfly, African butterfly fish and keelworm*

Genome resources, neglected taxa and the evolution of development

Genome sequencing, coupled with sequencing the entire messenger RNA content of particular cells and tissues, now provides the bedrock for studying groups of animals that have been largely bypassed by modern biology. Molluscs and annelids, for example, comprise roughly 100,000 and 12,000 described species respectively, yet we know very little about their development, genome organisation or genomic adaptations. Developing genome sequences and RNA catalogues for species such as the common limpet is enabling deeper study of their evolution, development and physiology. Here the development of pivotal structures such as the mollusc shell form a focus, as does the ability of shore-dwelling species to tolerate extreme stress, and the way in which early cell divisions are organised.

Mollusc and annelid embryos undergo a process known as spiral cleavage, where embryos going from four to eight cells twist the axis of cell division to the left or the right. This creates a spiral stacking of cells that directly determines whether adult features such as the spiral of a snail's shell are left-handed or right-handed. By integrating genome and RNA sequencing with gene expression studies and live embryo imaging, we are investigating how such asymmetries form, propagate and relate to asymmetries in other animals. Most surprisingly, it seems as though some aspects of this process are the same as those that control the asymmetric organisation of our own heart and guts, hinting at ancient mechanisms for making left and right different.

Planning for the future

As genome-level sequencing spreads through zoological research and with the increasing involvement of postgraduates and undergraduates, new challenges have arisen. Managing and manipulating the data needs significant computational power and data storage, as well as requiring students to develop bioinformatic skills. We have invested in new computational infrastructure to support this, as well as adapting graduate training and undergraduate teaching to promote bioinformatics: skills we think will become ever more valuable as the genomic revolution spreads.

Seb Shimeld

Using natural diversity to feed the future

It is predicted that by 2050 we will need to increase food production by at least 50%. At the same time, improvements in farm yields of our major crops has slowed down. This is clearly a serious global problem that needs to be addressed. There are few examples of inventions in the natural world that could produce such large increases in our domestic crops, but one that has this potential is known as C4 Photosynthesis. You can think of C4 photosynthesis as the plant equivalent of 'division of labour,' the idea that kick-started the industrial revolution. By dividing up the tasks of capturing CO_2 from the atmosphere and storing it as sugars into two different cells within the leaf, C4 plants essentially invented the production line and dramatically increased their overall efficiency. This saving allows them to grow more quickly and store more carbon in their leaves, seeds and fruits. Perhaps unsurprisingly given the advantage that this optimisation can confer, C4 photosynthesis has evolved at least 62 different times in at least 18 different families of plants. What's more, it's so efficient that although C4 plants only make up 3% of plants on earth they are responsible for 20–30% of all CO_2 capture by plants. The sheer number of times that C4 photosynthesis has been re-invented in nature combined with the urgent need to improve crop yields has led to international efforts to engineer C4 photosynthesis into non-C4 crops such as rice (http://c4rice.irri.org).

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Sorghum seedlings in C4 screenhouse

In our work, which is a collaborative effort linking Universities in Cambridge, Toronto, Alberta and the International Rice Research Institute in the Philippines, we are trying to learn from evolution how it is that C4 plants (like corn, sugar cane and millet) evolved from their non-C4 ancestors. One way in which we are currently doing this is by using new sequencing technologies to read and quantify the genes of more than 40 different C4 plants and their closest non-C4 relatives. Our discoveries are revealing the extent to which different species have used the same genes to achieve C4 photosynthesis and how many different ways evolution has found of reaching the same solution. We hope to use this information to engineer these changes into rice and thereby use natural diversity to feed the planet into the future.

Steve Kelly

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Harvesting rice

John Baker

Specimen of Sturt's pea (Swainsona formosa) *collected by the privateer William Dampier in August 1699 in Western Australia and housed in Oxford University Herbaria*

The Department of Plant Sciences Herbarium

When the University's herbarium, a collection of flattened dried plants, was established in 1621, biology as a discipline did not exist. Our knowledge of how plants worked was based on the experiences of foresters, farmers and physicians. Naturalists were concerned with ordering plant diversity, and identifying plants that could feed, kill or cure us. Fundamental plant functions, which we take for granted, were unappreciated, including sexual reproduction, light for plant growth and basic anatomy.

Plants gathered in gene banks and culture stocks are familiar to researchers working with model species, searching for gene function or breeding disease-resistant crops. However, the pedigree of scientific plant collections extends beyond the last century to the European Renaissance, when herbaria first became fundamental botanical tools. Herbaria record the physical evidence of the diversity and spatial and temporal distribution of the planet's plant life. Today, herbarium specimens, prepared using fifteenth-century technology, are being used to investigate twenty-first-century problems.

The University's herbarium (c. 1,000,000 specimens), packed into two rooms in

Peculiar plant sex chromosomes

Most plant species do not have separate sexes - male and female organs develop on the same individual or even in the same flower. This can have advantages; for example a plant separated from other individuals of the same species can still reproduce via self-fertilisation. On the other hand, the ability to self-fertilise may lead to inferior progeny because of inbreeding depression. Many plant groups developed a variety of mechanisms that prevents self-fertilisation, with some plants going as far as evolving separate males and females. These plant species have evolved sex chromosomes that control whether an individual develops as a male or a female, just like animals. This process has occurred many times and quite recently in some plant groups. For example, *Silene latifolia* (white campion) evolved sex chromosomes as recently as 5 to 10 million years ago, from ancestors that had neither separate sexes nor sex chromosomes. This provides an opportunity to study how separate sexes and sex chromosomes form and evolve.

The identification of a sufficient number of genes that are located on sex chromosomes (sex linked genes) has been a significant hurdle for understanding sex chromosome evolution in plants. Fewer than 12 sex-linked genes had been identified until the advent of high-throughput sequencing. We have now identified several hundred sex-linked genes from the *S. latifolia* genome in the last three years. This revealed a dynamic picture of sex chromosome evolution in *S. latifolia*.

Dmitry Filatov & Constantinos Groutidos

Closely related Silene latifolia *(white) and* Silene dioica *(pink) species grow side by side (and form hybrids) all over Europe. Both of these species have separate male and female individuals, which is determined by sex chromosomes. Similar to humans XX individuals of these species develop as females, while XY individuals become males*

To discover how sex chromosomes originated in *S. latifolia* we compared the location of genes in *S. latifolia* and *S. vulgaris* genetic maps. The latter species has no separate male and female individuals and no sex chromosomes, so it effectively shows us how the *S. latifolia* genome may have looked like before sex chromosomes evolved. This analysis revealed that *S. latifolia* sex chromosomes correspond to a single pair of chromosomes (autosomes) in *S. vulgaris*.

In order for the sex chromosomes to evolve from autosomes, recombination between the proto-X and –Y chromosomes must have stopped. We discovered that this happened in at least three distinct steps leaving distinctive marks along the chromosomes. Interestingly, this pattern has been found in many different animal species with sex chromosomes, so the evolutionary processes shaping sex chromosomes are similar in both kingdoms.

However, unlike the sex chromosomes of animals, we see little evidence of gene loss from the Y-chromosome in *S. latifolia*. This difference between the kingdoms may, at least partly, be due to fundamental difference in plant and animal life cycles. In plants a significant proportion of the genome is actively expressed at the haploid stage of life cycle, while in animals the genome is mostly inactive at this stage.

Dmitry Filatov

the Department of Plant Sciences, is the fourth oldest botanical collection in the world. It is part of a global network of approximately 2,600 herbaria, housing about 300,000,000 specimens. Plant collectors have spent their careers and, in some cases, their lives, combing the planet for specimens to populate herbaria. The global financial investment in herbaria through specimen collecting, curation and premises costs is enormous.

Traditionally, herbarium specimens are part of the evidence used to answer fundamental botanical questions. What plant is this? How many different plants are there? Where does this plant grow? How is this plant distributed globally? How does this plant's morphology vary across its range? To what is this plant related? It has been estimated that approximately 70,000 species of flowering plant remain to be named, of which about 35,000 have already been collected and are laying unnamed or wrongly named in the world's herbaria.

DNA extraction and pollen isolation from herbarium specimens has become commonplace giving researchers access to extinct species, or species impossible to collect for political, conservation, social or financial reasons. Importantly, the specimen automatically becomes the evidence (voucher) that a gene or pollen grain came from a particular species. These researchers take advantage of the often difficult fieldwork undertaken by others. Furthermore, the task of specimen identification is usually underestimated, especially by those working in areas replete with high-quality fieldguides.

As access to herbaria and the manipulation of large datasets has become easier, researchers from many disciplines, even if they have no direct interest in taxonomy, have recognised that the vast quantities of data filed in herbarium cabinets cannot be ignored. Herbarium data, amalgamated into international databases, are used to model processes of species introduction or changes in species' ranges due to climate change and even the provision of ecosystem services. Herbaria have risen to the self-evident challenge of digitising herbarium specimens and abstracting data. However, challenges with amalgamated data sets remain including collector and curator biases and the ever-present concern with specimen identification.

Herbaria are facilitators of research, where the limitations should be the imaginations of researchers and the quality of collections, not the bureaucracies of collection management. However, researchers demanding large datasets must be aware of the limitations inherent in herbarium data.

Stephen Harris

NEWSLETTER FOR BIOLOGY ALUMNI AND FRIENDS

This is the second edition of the Biology at Oxford newsletter.
We hope you like it, and we continue to welcome your comments.
See our website (www.biology.ox.ac.uk/alumni),
and email us on newsletter@biology.ox.ac.uk

UNIVERSITY OF OXFORD

Other websites:
www.alumni.ox.ac.uk; www.plants.ox.ac.uk; www.zoo.ox.ac.uk

OXFORD UNIVERSITY ALUMNI WEEKEND SEPTEMBER 2013

The Departments of Plant Sciences & Zoology
invite you to our Open Day in the Department of Zoology

SATURDAY 21ST SEPTEMBER 2013
1.00 PM TO 4.00 PM

ATTRACTIONS WILL INCLUDE TALKS:

Prof. David Macdonald, Director, WildCRU
'War and Peace : Living with Carnivores'
Prof. Nick Harberd, Sibthorpian Professor of Plant Sciences
'Mutation – Darwin's 'whatever the cause' '
Dr Stephen Harris, Druce Curator of the Oxford University Herbarium
'Conserving Biodiversity in the Face of Global Change'
Dr Steve Kelly, Systems Biology Research Fellow in Plant Sciences
'Using Genomics to Feed the World'

LAB TOURS & PRACTICAL DEMONSTRATIONS:

Plants Sciences Department:
DPhil students & postdocs
'Roots, Fruits & Shoots: Plant Science & Food Security'
Zoology Department:
Prof. Fritz Vollrath 'Silk – from Webs to Medical Implants'
Dr Theresa Burt de Perera & Dr Graham Taylor
'Flight and Swimming'

TEACHING DISPLAYS:

Dr Martin Speight, Admissions Coordinator for Biological Sciences
'Teaching Facilities in the Dept. of Zoology, Labs, Livestock & Lecture Courses'

Refreshments will be served

TO REGISTER PLACES, PLEASE EMAIL

alumni@biology.ox.ac.uk

Front cover: Female mosquito, *Anopheles albimanus*. Photo by James Gathany CDC