

Introduction to the Department

Overview

The Department of Zoology is a large, multi-disciplinary Department whose members conduct research and teaching in areas ranging from molecular biology to ecology.

We can offer excellent opportunities and facilities for training in research, leading to the degree of PhD (Doctor of Philosophy), or MPhil (Master of Philosophy in the Biological Sciences). Both the University of Cambridge and the Department have an international reputation for their education and research.

The Department is located on the New Museums site in central Cambridge and incorporates the Museum of Zoology, which contains important research collections, including items from Darwin's *Beagle* voyage. Some members of staff are housed in the nearby Austin Building, and in the Wellcome Trust/Cancer Research UK Gurdon Institute, a short distance away in Tennis Court Road. The Sub-Department of Animal Behaviour is located in the village of Madingley, about four miles from Cambridge.

The Department has an extensive library, plus on-site facilities for confocal microscopy, electronics, computing, instrument making, biochemistry and molecular biology.

The principal areas of research are given below.

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Staff, Research Facilities and Postgraduate Studies

At present the Department consists of around 350 people, including graduate students, research staff, assistant staff and University Lecturers, Readers and Professors. Within the Department there are 17 Fellows of the Royal Society, 3 of who are also members of Academia Europea. Research students may be supervised by academic staff of the University or by group leaders of research units based at the Wellcome Trust/Cancer Research UK Gurdon Institute.

The research of the Department is supported by approximately 80 research grants with a total value in excess of £27m. These grants are principally from British sources, e.g. the Research Councils - BBSRC, NERC and EPSRC - charities such as the Cancer Research Campaign and Wellcome Trust, and other bodies, including The Royal Society and Leverhulme Trust. They also include awards from prestigious international organisations such as the National Institutes of Health in the United States and from the European Union.

With its large population of post-docs and graduates, many of whom come from overseas, and its wide diversity of teaching and research, the Department provides a good environment for the informal meeting of scientists of varied expertise and background. This informal contact is positively encouraged and there is a Common Room where all members of the Department may meet for tea, coffee and other refreshments. In addition, there is an active social programme run by the graduate students, including informal talks for presenting their work. Students are expected to give a talk each year to a general audience, and most research groups organise their own seminar series and weekly group meetings. The Department runs various seminar series and lecture programmes throughout the year and students are also encouraged to attend the wide range of courses and talks arranged by other biological departments and institutions in and around Cambridge.

All graduate students have a supervisor to take primary responsibility for overseeing their research. Two academic advisors are also appointed for each student to provide further expertise in the relevant research area and monitor progress by assessing written reports. These assessments are fed back to the Department's Graduate Education Committee. The aim of this monitoring is to ensure that all students have the facilities and support they need, receive the training required to enhance their career prospects and are on course to finish their thesis within the allotted time.

The Graduate School of the Life Sciences (GSLs) provides extensive information for graduate students, including details of courses, a directory of experts, a students' forum and what it means to be a graduate student in Cambridge.

<http://www.biomed.cam.ac.uk/gradschool/>

The University and the Colleges

Cambridge is a collegiate university, so graduate students are also members of a college. This provides a social base within the University, a graduate tutor as a further source of wisdom, and may also be able to assist with accommodation and additional funding. In contrast to undergraduate teaching, some of which is arranged

by the college, graduate student research programmes are organised entirely by the Department.

The choice of college is a personal one; some graduate students prefer to choose a graduates-only college, such as Darwin, whilst others opt for colleges with a mix of undergraduates and postgraduates. Applicants will find detailed information on the Graduate School website. <http://www.admin.cam.ac.uk/univ/gsprospectus/colleges/>

Fees

The University and the Colleges both charge annual fees. The University fees, (known as composition fees) in 2010/11 were £3,490 a year for UK and EU students, and £14,073 a year for overseas students. Such fees are likely to rise annually with inflation. If you are a UK or EU student and are awarded a Research Council studentship, these fees are paid automatically. The college fee is the same for both UK/EU and overseas students, and varies between colleges, but the average this year is £2,250 per annum.

An overseas student is generally defined as someone who has not ordinarily been resident in the UK for a three year period preceding the commencement of his or her course and is not a national of a member state of the European Union, or the son, daughter or ward of such a national. This is, however, not an exhaustive definition and further enquiries about eligibility should be addressed to the Board of Graduate Studies. <http://www.admin.cam.ac.uk/offices/gradstud/admissions/>

The University also requires students to prove they have sufficient funds to adequately cover their living expenses for the duration of their period of study.

The PhD and MPhil Degrees

The **PhD** degree is a three or four year course of research, at the end of which the student submits a dissertation and defends this in an oral (viva) examination. The **MPhil** degree is a one year course of research, again culminating in the submission of a dissertation and a viva. Both include formal coursework, and although this is not examined, progress is closely monitored by means of written reports to the Department's Graduate Education Committee.

The University expects applicants to possess a good first degree, which might be enhanced by a master's degree, although this is not a prerequisite for a PhD. For details on academic criteria please refer to the Board of Graduate Studies website at <http://www.admin.cam.ac.uk/offices/gradstud/admissions/>

The academic year for the University begins on 1 October and most students take up their studentships then, although other starting dates, such as January or April, are possible. We expect students studying for the PhD degree to complete their experimental work within three years, and their dissertation within four years.

How to apply:

Informal enquiries should be addressed to:-

Linda Wheatley,
Graduate Administrator,
Department of Zoology,
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Downing Street,
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- **Visit our website at** <http://www.zoo.cam.ac.uk>
Check the research interests of members of staff.
- **Find a Supervisor**
Prospective students should contact a potential supervisor before applying to discuss ideas for research projects and, if at all possible, to arrange a visit.

Formal applications are made **online**; forms are available from the Board of Graduate Studies website at <http://www.admin.cam.ac.uk/offices/gradstud/admissions/>

This is usually the last step in the applications process. There is a fee of £35. This is one reason why we strongly encourage you to make an informal enquiry in the first instance.

Deadlines:

Students from Overseas and the EU who wish to be considered for Cambridge-based sources of funding (e.g. the Gates Cambridge Trust, the Cambridge Overseas and Cambridge Commonwealth Trusts, Cambridge International Scholarships Scheme (CISS), Cambridge Home and European Scholarships Scheme (CHESS) and others) should check the websites of both the Board of Graduate Studies and the Graduate School of the Life Sciences for deadlines.

Note: The deadline for Gates Cambridge Scholarships for **US** citizens is 15 October 2010; for candidates from the **Rest of the World** it is 1 December 2010.

The Department will advertise available scholarships **on its own webpages** via a link from our homepage:
<http://www.zoo.cam.ac.uk/>

We suggest you check regularly for details of projects, application procedures and deadlines.

CELL BIOLOGY

We study fundamental aspects of cell biology, including DNA repair and replication, cell division, gene expression, endocytosis and cell signalling. Our research aims to elucidate the mechanisms and importance of cell biological processes through approaches that range all the way from the study of individual genes and proteins up to their roles in the behaviour, physiology, development and evolution of animals. To achieve this we use a range of model systems, including cell free extracts, mammalian tissue culture cells, yeast, *Caenorhabditis elegans* and *Drosophila*.

Regulation of mitosis by proteolysis and cyclin-dependent kinases

DR JONATHAN PINES

Wellcome Trust/Cancer Research UK
Gurdon Institute of Cancer and Developmental Biology

The fundamental aim of mitosis is to ensure that a dividing cell generates two daughter cells with identical sets of chromosomes. To achieve this, the entire subcellular architecture of the cell is reorganized and sister chromatids are pulled apart by the mitotic spindle, but only after all the chromosomes have properly attached to it. We are trying to understand how the cell coordinates these dramatic events, and are focusing on the protein kinases and ubiquitin ligases that control mitosis. We are combining live-cell imaging, to capture the rapid and highly dynamic changes of mitosis, with protein biochemistry, in particular mass-spectrometry analysis, to identify the components of the machinery that control them. Currently we are using Förster Resonance Transfer probes to measure kinase activity in cells as they divide, and GFP-tagged substrates to assay the activity of the Anaphase Promoting Complex/Cyclosome (APC/C) and determine how this ubiquitin ligase is able to select different proteins for destruction at different times in mitosis. Our recent studies have begun to reveal how cells prevent sister chromatids from separating prematurely through the Spindle Assembly Checkpoint that acts on the APC/C, and how some proteins, such as Cyclin A, can be degraded independently of the checkpoint.

Further information is available on the web:

<http://www.gurdon.cam.ac.uk/pines.html>

Gavet, O. and **Pines, J.** (2010)

Progressive activation of Cyclin B1-Cdk 1 coordinates entry to mitosis. *Dev Cell* **18**: 533-543.

Nilsson, J., Yekezare, M., Minshull, J. and **Pines, J.** (2008)

The APC/C maintains the spindle assembly checkpoint by targeting Cdc20 for destruction. *Nat. Cell Biol.* **10**: 1411-1420.

Wolthuis, R., Clay-Farrace, L., van Zon, W., Yekezare, M., Ogink, J., Medema, R. and **Pines, J.** (2008)

Cdc20 and Cks Direct the Spindle Checkpoint-Independent Destruction of Cyclin A. *Mol. Cell* **30**: 290-302.

Di Fiore, B. and **Pines, J.** (2007). Emi1 is needed to couple DNA replication with mitosis but does not regulate activation of the mitotic APC/C. *J. Cell Biol.* **177**, 425-437.

The Regulation of Replication Initiation in Eukaryotes

DR PHILIP ZEGERMAN

Wellcome Trust/Cancer Research UK
Gurdon Institute of Cancer and Developmental Biology

To successfully pass on their genetic information, every organism must make a perfect duplicate of their genome in every cell cycle. Failure to copy every chromosome faithfully leads to genomic instability, which is the root cause of cancer. As a result, eukaryotes strictly regulate replication initiation, both within the normal cell cycle and after DNA damage. A key step in the initiation of replication is the formation of the pre-initiation complex – pre-IC. We have shown that it is components of the pre-IC that are the fundamental targets of both the pivotal cell-cycle kinase, cyclin-dependent kinase (CDK), and the DNA damage response kinase Rad53 (Chk2) in the budding yeast *Saccharomyces cerevisiae*. This work raises several fundamental questions:

What is the role of the pre-IC in replication initiation?

Is the function of the pre-IC conserved in other eukaryotes?

We aim to address these questions through genetic and biochemical analysis of the pre-IC proteins across three model systems; budding yeast, the nematode worm *Caenorhabditis elegans* and cultured human cells. Comparing the properties of these essential replication initiation factors in different organisms will give fundamental insight into the function of these proteins in eukaryotes. In addition, *C.elegans* provides a powerful genetic platform to screen for novel metazoan replication initiation factors by whole genome RNAi. Since many replication initiation genes are mutated in human cancers, understanding this step in genome duplication is vital for cancer research.

Further information is available on the web:
<http://www.gurdon.cam.ac.uk/~zegermanlab/>

Zegerman, P. and Diffley, J.F. (2009)
Checkpoint dependent inhibition of DNA replication initiation via phosphorylation of Sld3 and Dbf4.
Nature. Under revision.

Zegerman, P. and Diffley, J.F. (2009)
DNA replication as a target of the DNA damage checkpoint.
DNA Repair **8**:1077-88.

Zegerman P. and Diffley, J.F. (2007)
Phosphorylation of Sld2 and Sld3 by cyclin-dependent kinases promotes DNA replication in budding yeast.
Nature **445**:281-5

Zegerman, P. and Diffley, J.F. (2003)
Lessons in how to hold a fork.
Nature Struct Biol.

Regulation of Chromosomal DNA Replication in Human Cells

DR TORSTEN KRUDE

The genetic information of a eukaryotic cell is encoded in its chromosomal DNA, which is located in the cell nucleus. Before a cell can divide successfully, its entire chromosomal DNA has to be replicated precisely once to ensure propagation of its information down the generations. A key event in this regulation is the initiation step at the G1 to S phase transition of the cell division cycle.

To investigate the initiation of chromosomal DNA replication at molecular level, we have established a cell-free system from human somatic cells that reconstitutes this reaction in the test tube. Template nuclei for DNA replication in this system are isolated from cells synchronized in the late G1 phase of the cell division cycle, and their incubation in a cytosolic extract from proliferating cells leads to the establishment of replication forks in these nuclei.

Our main research focus is the identification and characterization of new initiation factors, which are present in the cytosolic extract. We are using a wide range of techniques, including cell culture, biochemical fractionation and functional reconstitution assays, mass spectrometry, molecular biology and confocal fluorescence microscopy.

We have recently identified a new class of replication factors, which turned out to be small non-coding stem-loop RNAs, termed Y RNAs. We are currently investigating the molecular mechanisms by which Y RNAs regulate chromosomal DNA replication. Key questions are, for example: what replication proteins interact with Y RNAs and do Y RNAs modulate the activities of these interacting proteins? Furthermore, we wish to learn more about the roles of Y RNAs in vertebrate development; and about the regulation of their expression, intracellular localization and additional functions in the cell.

More information is available on our lab website:

<http://www.zoo.cam.ac.uk/zoostaff/krude/index.html>

Krude, T., Christov, C.P., Hyrien, O., and Marheineke, K. (2009)
Y RNA functions at the initiation step of mammalian chromosomal DNA replication.
J Cell Sci **122**: 2836-2845.

Gardiner, T.J., Christov, C.P., Langley, A.R., and **Krude, T.** (2009)
A conserved motif of vertebrate Y RNAs essential for chromosomal DNA replication.
RNA **15**: 1375-1385.

Christov, C.P., Trivier, E., and **Krude, T.** (2008)
Noncoding human Y RNAs are overexpressed in tumours and required for cell proliferation.
Br J Cancer **98**: 981-988.

Christo, C.P., Gardiner, T.J., Szüts, D. and **Krude, T.** (2006)
Functional requirement of non-coding Y RNAs for human chromosomal DNA replication.
Mol. Cell Biol **26**: 6993-7004.

Krude, T. (2006).
Initiation of chromosomal DNA replication in mammalian cell-free systems.
(Review article) *Cell Cycle* **5**: 2115-2122.

Protein-protein interactions during DNA replication

DR CATHERINE M GREEN

The replication of the genome must be performed completely and accurately once in each cell cycle in order to maintain genome stability and to minimise mutations that can lead to cancer development. The process of DNA replication comprises a series of enzymatic steps that must be temporally and spatially controlled within the cell nucleus if errors are to be avoided. We are investigating this control at a molecular level by analyzing interactions and associations between proteins that perform replicative functions both *in vitro* and *in vivo*.

My lab is mainly funded by a Career Development Fellowship Cancer Research UK. Our main focus is an investigation of protein traffic on a key replication protein, proliferating cell nuclear antigen (PCNA). PCNA is a ring shaped protein that encircles the template DNA and can slide along the linear DNA molecule. Any proteins that interact with PCNA are therefore brought in close proximity to the DNA. PCNA is known to interact with proteins essential for all stages of the replication process, including polymerases, nucleases, ligases and helicases. PCNA is also important for ensuring that chromatin and epigenetic marks are correctly assembled onto replicated DNA as well as for DNA repair events and also for controlling the time in the cell cycle at which replication is permitted. In fact more than 70 different proteins have been shown to interact with PCNA. Our overall aim is to understand how these multiple interactions can be constrained so that only the appropriate ones occur at any particular time and place.

To achieve this aim we use a variety of methods to analyse interactions between proteins. These include: *in vitro* analysis of interactions between replication proteins by surface plasmon resonance (SPR); *in vitro* and *in vivo* analyses of protein associations by fluorescence resonance energy transfer (FRET); and biochemical purification of replication protein complexes.

Further information is available on the web:

http://www.zoo.cam.ac.uk/zoostaff/Green_Lab/Homepage.html

Ramasubramanian, S., Coulon, S., Fuchs, R.P., Lehmann, A.R. and **Green C.M.** (2010) Ubiquitin-PCNA fusion as a mimic for mono-ubiquitinated PCNA in *Schizosaccharomyces pombe*. *DNA Repair (Amst)*. **9(7)**:777-84.

Bienko, M., **Green, C.M.**, Sabbioneda, S., Crosetto, N., Matic, I., Hibbert, R.G., Begovic, T., Niimi, A., Mann, M., Lehmann, A.R. and Dikic, I. (2010) Regulation of translesion synthesis DNA polymerase eta by monoubiquitination. *Mol Cell*. **37(3)**:396-407.

Cseresnyes, Z., Schwarz, U. and **Green, C.M.** (2009) Analysis of replication factories in human cells by super-resolution light microscopy. *BMC Cell Biol*. **10**:88.

Lehmann, A.R., Niimi, A., Ogi, T., Brown, S., Sabbioneda, S., Wing, J.F., Kannouche, P.L. and **Green C.M.** (2007) Translesion synthesis: Y-family polymerases and the polymerase switch. *DNA Repair (Amst)*. **6(7)**: 891-9

Green, C.M. (2006) One ring to rule them all? Another cellular responsibility for PCNA. *Trends Mol Med*. **10**: 455-8

Integrated studies of cell signalling in *C. elegans*

DR HOWARD A BAYLIS

Our research addresses how intracellular signalling networks control animal biology. We use the model organism *C. elegans* and utilise a range of molecular, cell biological and whole animal techniques. Possible projects include:

1. How do Alzheimer's disease genes control calcium signalling?

Mutations in presenilin genes are the most common cause of inherited Alzheimer's disease and are known to cause changes in calcium signalling. The mechanisms underlying these changes and their importance to Alzheimer's disease remain unclear. We are investigating how presenilins regulate calcium signalling in the nervous system.

2. How do presenilins control neuronal function?

We have also shown that mutations in presenilins cause changes in synaptic function, an observation that has also been made in mammals. We now wish to understand the role of presenilins in neurotransmission.

3. The mechanisms of signal specificity in polymodal neurones.

Many sensory neurones (e.g. pain nociceptors) are polymodal; that is they respond to a range of different stimuli. How they respond to and transduce information about specific stimuli is unclear. We have shown that in the ASH neurones of *C. elegans* IP₃ and Ca²⁺ signalling are important to two specific responses. We now wish to further dissect these signalling pathways and to test the hypothesis that one of them is a novel signalling pathway.

4. RNAi hypersensitivity in IP₃ receptor mutants.

We have discovered that IP₃ receptor mutants are hypersensitive to RNAi. This is the first time that a signalling molecule has been implicated in determining the sensitivity of animals to RNAi. How does this signalling pathway regulate the RNAi response?

Further information is available on the web:

<http://www.zoo.cam.ac.uk/zoostaff/baylis/homepage.html>

Walker D S, Vazquez-Manrique R P, Gower N J D, Gregory E, Schafer W R and **Baylis H A** (2009) Inositol 1,4,5-trisphosphate signalling regulates the avoidance response to nose touch in *Caenorhabditis elegans*. *PLoS Genet* **5**: e1000636. doi:10.1371/journal.pgen.1000636

Parker S P, Walker D S, Ly S and **Baylis H A** (2009) Caveolin-2 is required for apical lipid trafficking and suppresses basolateral recycling defects in the intestine of *Caenorhabditis elegans*. *Mol Biol Cell* **20**, 1763-1771,

Vazquez-Manrique, R.P., Nagy, A.I., Legg, J.C., Bales, O.A.M., Ly, S. and **Baylis, H.A.** (2008) Phospholipase C- ϵ Regulates Epidermal Morphogenesis in *Caenorhabditis elegans*. *PLoS Genet* **4**: e1000043. doi:10.1371/journal.pgen.1000043

Baylis, H.A. (2005)

Vav's got rhythm.

Cell **123**: 5-7

DEVELOPMENTAL BIOLOGY

Many areas of developmental biology have been galvanized by the application of molecular and genetic techniques. The Department is well-equipped for most kinds of fundamental research in these fields, with particular emphasis on the role of cell interactions in the development of pattern. Studies of development and cell differentiation in *Xenopus* and *Drosophila* are exceptionally well represented.

Development of Dendrites and Synaptic Connectivity in an Embryonic Motor System

DR MATTHIAS LANDGRAF

We are interested in understanding how neural networks that underlie behaviour are generated. As a model system we work with the locomotor network of the fruit fly larva, *Drosophila melanogaster*. This system has many advantages, notably its powerful genetics and being composed of identified neurons that are amenable to genetic manipulation and interrogation throughout development by imaging and electrophysiology.

There are many angles from which network specification and assembly can be addressed, each offering possibilities for research projects.

Organisation of the network

We discovered a clear organizational logic that underlies connectivity in the network. Motorneurons put their dendrites, the branched structures that receive connections from other cells, into distinct regions of the nervous system in a myotopic fashion: the distribution of motorneuron dendrites in the central nervous system mirrors the distribution of their body wall muscles in the periphery. This may be a conserved organizational principle of motor systems as analogous arrangements of motorneuron dendrites have since been found in other motor systems, including the mouse spinal cord.

We are studying the cellular and molecular mechanisms that generate this dendritic myotopic map. We found that the particular responsiveness of neurons to guidance cues determines the locations where they put their presynaptic axon terminals and postsynaptic dendritic arbors. They seem to do so independently of their partner terminals or neural activity suggesting that the basic architecture of the network is specified by cell intrinsic programmes, e.g. the expression of cell-specific combinations of guidance cue receptors, which deliver partner terminals to common 'meeting regions'.

Having identified the main cues that position dendrites with respect to the ventral midline, we are now investigating how distinct antero-posterior distributions are generated and how dendrites and axons of the same neuron can respond differentially to the same cues.

Connectivity

Large scale genetic screens are underway designed to identify the interneurons required for normal locomotor network function. We are using state-of-the-art genetic intersectional strategies to drive gene expression in defined sets of cells. We test neuronal function by manipulating activity using genetically targeted warmth and light activated ion channels, measuring the effects of these manipulations by electrophysiology and behavioural analysis. One issue under investigation is how

connectivity in the network is organized at other levels. For example, how is the myotopic map of motorneuron dendrites represented by pre-motor interneurons? Having identified several candidate pre-motor interneurons we are studying how actual sets of connections between identified partner neurons develop and ask to what extent these are reproducible and how is such specificity generated.

Dendritic growth and maturation of network connectivity

Live imaging shows that dendritic arbors are dynamic structures. Using high resolution confocal imaging and quantitative analysis of digitally reconstructed dendritic arbors we have demonstrated that dendritic growth is regulated by synaptic contacts with partner terminals and their activity. We are now investigating the signals and cellular and molecular mechanisms that regulate the dynamics of dendritic growth and synapse development. By imaging identified partner neurons as the nervous system develops we are exploring how sets of connections form and how these are adjusted as the network matures and function emerges.

Further information is available on the web:

<http://www.zoo.cam.ac.uk/zoostaff/ndd/>

Mauss, A., Tripodi, M., Evers, J.F. and **Landgraf, M.** (2009).

Midline signalling systems direct the formation of a neural map by dendritic targeting in the *Drosophila* motor system. *PLoS Biol* **7**, e1000200.

Tripodi, M., Evers, J.F., Mauss, A., Bate, M. and **Landgraf, M.** (2008).

Structural homeostasis: compensatory adjustments of dendritic arbor geometry in response to variations of synaptic input. *PLoS Biol* **10**, E260.

Ou, Y., Chwalla, B., **Landgraf, M.** and van Meyel, D. J. (2008)

Identification of genes influencing dendrite morphogenesis in developing peripheral sensory and central motor neurons. *Neural Development* **3**: 16

Landgraf, M. and Thor, S. (2006)

Development of motorneurons: specification and dendritic morphology. In: "Drosophila as a model for understanding development and function of the Central Nervous System" (ed. R A Baines and M Landgraf) *Seminars in Cell and Developmental Biology* **17**: 3-11

Landgraf, M., Jeffery, V., Fujioka, M., Jaynes, J.B. and Bate, M. (2003)

Embryonic origins of a motor system: motor dendrites form a myotopic map in *Drosophila*. *PLoS-Biology* **1**: E41

Organogenesis: development of excretory tissues in *Drosophila*

DR BARRY DENHOLM

Organogenesis describes the processes by which groups of cells come together and assemble into specialized tissues and organs with characteristic shapes, sizes and functions. In the lab we're interested in these processes, how they are controlled and how they are integrated with one another. Our experimental model of choice is the fly excretory system. This system consists of two main components: renal (Malpighian) tubules and nephrocytes that together regulate haemolymph (insect blood) composition. This is a simple organ system benefiting from ease of experimental manipulation and tractable genetics afforded by the fly, but also one that shares many features with more complex organs such as the vertebrate kidney. By using a combination of genetic, genomic, cell, and physiological techniques we are exploring the processes that underpin development of the fly excretory system to gain fundamental insights into organogenesis.

We have recently shown that fly nephrocytes bear striking resemblance to the podocyte of the vertebrate kidney. In particular, nephrocytes make a filtration barrier that is structurally, molecularly and functionally highly similar to the podocyte slit diaphragm, the main size-selective barrier in the kidney as blood is ultrafiltered to make urine. This work, and previous studies in other invertebrates, suggests that invertebrate excretory systems may be more related to the vertebrate kidney than previously thought. We are studying the development, cell biology and physiology of the nephrocyte to learn more about this important part of the insect excretory system and, in collaboration with clinical scientists, we are using the nephrocyte as a model to study podocyte biology and podocyte-associated diseases.

In the future, we would also like to explore the evolutionary relationship between animal excretory organs by comparing the molecular make-up that underpins excretory organ development and function across a range of invertebrate animals.

More information is available on the web:

<http://www.zoo.cam.ac.uk/zoostaff/skaer/lab/denholm.htm>

Denholm, B., and Skaer, H. (2009) Bringing together components of the fly renal system.

Current Opinions in Genetics and Development **19**(5):526-32

Weavers, H, Prieto-Sánchez, S, Grawe, F, Garcia-López, A, Artero, R, Wilsch-Bräuninger, M, Ruiz-Gómez, M, Skaer, H, **Denholm, B.** (2009). The insect nephrocyte is a podocyte-like cell with a filtration slit diaphragm. *Nature* **457**: 322-326

Simões S, **Denholm B**, Sotillos S, Martin P, Skaer H, Castelli-Gair Hombría J, and Jacinto A. (2006). Compartmentalization of Rho regulators directs cell invagination during tissue morphogenesis. *Development* **133**(21) 4257-67

Denholm B, Brown S, Ray RP, Ruiz-Gomez M, Skaer H, Hombría JC. (2005). *crossveinless-c* is a RhoGAP required for actin reorganisation during morphogenesis. *Development* **132**(10):2389-400

Jung AC, **Denholm B**, Skaer H, Affolter M. (2005). Renal tubule development in *Drosophila*: a closer look at the cellular level. *J Am Soc Nephrol.* **16**(2):322-8

Denholm, B. and Skaer, H. (2005). Development of Malpighian tubules in insects. In *Comprehensive Molecular Insect Science*, Vol 2 (ed. L.I. Gilbert, S. Gill and K. Iatrou), pp. 291-314. Oxford, UK: Elsevier.

Denholm, B. *et al* (2003).

Dual origin of the renal tubules in *Drosophila*: mesodermal cells integrate and polarize to establish secretory function. *Current Biology.* **13**(12):1052-7.

Developmental and Functional Crosstalk between the Nervous System and the Intestine

DR IRENE MIGUEL-ALIAGA

It is currently unclear why we have 500 million neurons in our gut, but it is becoming apparent that the crosstalk between these neurons, the intestine and the central brain is key to the regulation of appetite and metabolism. Indeed, mounting evidence links largely uncharacterized signals emanating from the intestine to increasingly prevalent conditions such as diabetes and metabolic syndrome.

Research in the lab investigates how intestinal neurons are formed and how they function using the fruit fly *Drosophila melanogaster*. We share over 60% of our genes with the fruit fly but its digestive tract is simpler than ours and has fewer neurons, so it is easier to study. It is also relatively straightforward to switch specific *Drosophila* genes or neurons on and off. We are combining these genetic manipulations with behavioural and physiological methods that we have recently developed to investigate how intestinal neurons are specified during embryonic development and how they regulate body weight, appetite and the functions of internal organs in larvae or adult flies.

Using these approaches, we have already identified a brain-gut circuit of intestinal neurons that secrete insulin-like peptides and regulate food intake. A student could pursue one of the following questions or develop his/her own PhD interests within the lab's broad framework.

- How are visceral fates specified during development? (i.e. how does a neuron know to become an intestinal neuron?)
- How do these intestinal neurons control; intestinal mobility, absorption and secretion?
- What is the nature and significance of the signals that the intestine uses to "talk back" to the brain?

Further information is available on the web:

<http://www.zoo.cam.ac.uk/zoostaff/miguel-aliaga.html>

Cognigni, P., Bailey, A.P., Gould, A.P., Maddrell, S. and **Miguel-Aliaga, I.** (2010)
Enteric neurons and hormonal signals couple nutritional and reproductive status with intestinal homeostasis. *Under review*.

Miguel-Aliaga, I., Thor, S. and Gould, A.P. (2008)
Postmitotic specification of *Drosophila* insulineric neurons from pioneer neurons. *PLoS Biol* **11:6(3)**:e58.

Baumgardt, M., **Miguel-Aliaga, I.**, Karlsson, D., Ekman, H. and Thor, S. (2007)
Specification of neuronal identities by feedforward combinatorial coding. *PLoS Biol* **5(2)**:e37.

Miguel-Aliaga, I. and Thor, S. (2004)
Segment-specific prevention of pioneer neuron apoptosis by cell-autonomous, postmitotic Hox gene activity. *Development* **131(24)**:6093-105.

Miguel-Aliaga, I., Allan, D.W. and Thor, S. (2004)
Independent roles of the *dachshund* and *eyes absent* genes in BMP signaling, axon pathfinding and neuronal specification. *Development* **131(23)**:5837-48.

Regulation of cell polarity by motor proteins and RNA localization during development

DR ISABEL PALACIOS

Research in the lab is directed towards understanding the mechanisms involved in the early development of an organism, including RNA processing and how asymmetries are generated at the single cell level. More specifically, we have been studying the function of the motor protein Kinesin in establishing these asymmetries, and the mechanism by which localised mRNAs are distributed within the cell. We are employing biochemical, cell biological and genetic approaches to study these processes in the fruitfly *Drosophila melanogaster*.

Molecular motor proteins such as Kinesin are responsible for many of the major microtubule-dependent transport pathways in neuronal and non-neuronal cells. Elucidating these pathways is an area of increasing importance and intense investigation, with possible implications in human diseases, such as neurodegeneration. We are using the *Drosophila* oocyte as a model system to study the nature of the cargoes moved by Kinesin, to identify the proteins that link kinesin to these cargoes and to analyse how the activity of Kinesin is modulated by these interactions.

One of the cargoes of Kinesin is *oskar* mRNA, whose localisation in the oocyte is essential to define the anterior-posterior axis of the embryo. In general, RNA localisation plays an essential role in the determination of cell polarity and body asymmetries. We are studying the Kinesin-dependent localisation of *oskar* mRNA as a model system to understand how RNAs are asymmetrically distributed to specific regions in the cell.

To further understand how mRNAs localise, we are also studying the proteins that directly interact with the transcript and form the localisation complex, such as the exon-exon junction complex. We have previously shown that this protein complex is conserved in mammals, where it functions in non-sense-mediated mRNA decay (NMD), a RNA surveillance mechanism that is essential for proper gene expression. The NMD pathway has a direct impact on hundreds of genetic disorders; about a quarter of all known mutations are predicted to trigger NMD. We are interested in analysing further what is the relation of these two post-transcriptional events: mRNA localization and mRNA surveillance.

Further information is available on the web:

<http://www.zoo.cam.ac.uk/zoostaff/palacios.html>

Palacios, I.M. and St Johnston D. (2002).

Kinesin light chain-independent function of the Kinesin heavy chain in cytoplasmic streaming, and posterior localisation in the *Drosophila* oocyte. *Development* **129(23)**:5473-85

Benton, R, **Palacios, I.M.** and St Johnston D. (2002). *Drosophila* 14-3-3/PAR-5 is an essential mediator of PAR-1 function in axis formation. *Developmental Cell* **3(5)**:659-71

Palacios, I.M., Gatfield, D., St Johnston, D. and Izaurralde, E. (2004). An eIF4AIII-containing complex required for mRNA localisation and nonsense-mediated mRNA delay. *Nature* **427**: 753-57

Palacios, I.M. (2007). How does an mRNA find its way? Intracellular localisation of transcripts. *Seminars in Cell & Developmental Biology* Apr **18 (2)**: 163-70.

Meignin, C., Alvarez-Garcia, I., Davis, I. and **Palacios, I.M.** (2007) The Salvador-warts-hippo-pathway is required for epithelial proliferation and axis specification in *Drosophila*.

Current Biology **17 (21)**: 1871-8

Loiseau, P., Davies, T., Williams, L.S., Mishima, M. and **Palacios, I.M.** (2010)

Drosophila Pat1 is required for Kinesin-1 to transport cargo and to maximize its motility.

Development. In Press

NEUROBIOLOGY

Neurobiology seeks to explain the mechanisms that generate behaviour at all levels, from molecule to cell, through circuits to computation, and then to behaviour. Our group exemplifies this biological approach and enables us to offer students projects with a mix of techniques, and a combination of disciplines, that matches their particular interest. We have strong links to other groups in the Department and the University working on the molecular biology of signalling in the nervous system, developmental neurobiology and computational neuroscience.

Principles governing the function and design of eyes, neural circuits and brains

PROFESSOR SIMON B LAUGHLIN

Insects afford an exceptional opportunity to examine the design principles that underlie both the mechanisms of vision, and the design and evolution of neurons and neural circuits and brains. Taking advantage of the unusually well defined neuro-anatomy and molecular genetics of flies, we use electrophysiological techniques to describe the flow of information within, and between identified cells, in the intact and fully functional nervous system. This description is combined with modelling and with studies of behaviour to see how neural circuits are designed to extract biologically relevant information speedily and efficiently. We are investigating five related topics:-

- the molecular and cellular design of photoreceptors and neurons
- adaptation and coding efficiency
- the coding and integration of motion signals
- the role played by metabolic costs in determining the design and evolution of neurons, eyes and brains
- visual ecology

Our findings often reveal general principles of operation and design that apply to all aspects of visual neuroscience, and to neurobiology as a whole.

Further information is available on the web:

<http://www.zoo.cam.ac.uk/zoostaff/laughlin/>

Laughlin, S.B. (2004)

The implications of metabolic energy requirements in the representation of information in neurons. In *The Cognitive Neurosciences III*, (ed. M.S. Gazzaniga), pp. 187-196. Cambridge MA: MIT Press.

Niven, J.E., Anderson, J.C. and **Laughlin, S.B.** (2007)

Fly photoreceptors demonstrate energy-information trade-offs in neural coding. *PLoS Biology* **5**(4): 828-840

Niven, J.E. and **Laughlin, S.B.** (2008)

Energy limitation as a selective pressure on the evolution of sensory systems. *J. Experimental Biol.* **211**: 1792-1804

Parsons, M.M., Krapp, H.G. and **Laughlin, S.B.** (2010)

Sensor fusion in identified visual interneurons. *Curr. Biol.* **20**: 624-628

Integration in small neuronal networks

PROFESSOR MALCOLM BURROWS

Analysing insects gives important insights into the organisation of neurons in the central nervous system for the generation and control of natural movements. Our analysis links the actions of neurons directly to the behaviour in which they are involved and uses a combination of intracellular recording and staining methods, behavioural analyses with high-speed video, antibody staining, pharmacology, calcium imaging and confocal microscopy.

Three projections exploit this approach:

1. The evolution of jumping mechanisms

Jumping is an extreme act that requires specialisations of the nervous system to generate complex motor patterns, of the muscles to generate the large forces, and the joints to give the appropriate mechanical advantages and to withstand the forces. Following a detailed analysis of the neuronal mechanisms in locusts and grasshoppers, attention is now focused on jumping in plant sucking bugs. This diverse group includes the best jumping insect, the froghopper. Other members have evolved different features of the general strategy for jumping thus presenting a wide range of specialisations. How do these insects jump so well?

Burrows, M. (2003) Froghopper insects leap to new heights. *Nature* **424**: 509.

2. Neuronal mechanisms of phase transitions in locusts

Locusts can live in a solitary state in which individuals actively avoid each other, or in a gregarious state when they join together in dense groups. The behaviour, the actions of identified neurons, and the distribution and amounts of different neurotransmitters and neuromodulators are different in the two phases. Mechanical stimulation of particular hairs on the hind legs can change a solitary into a behaviourally gregarious locust within 4 hours. We are analysing the changes in the nervous systems and in particular in the neurons, to understand the underlying differences between the two phases.

Rogers, S. M., Matheson, T., Sasaki, K., Kendrick, K., Simpson, S. J. and **Burrows, M.** (2004).

Substantial changes in central nervous system neurotransmitters and neuromodulators accompany phase change in the locust. *J Exp. Biol.* **207**: 3603-17.

Matheson, T., Rogers, S. M. and Krapp, H. G. (2004).

Plasticity in the visual system is correlated with a change in lifestyle of solitary and gregarious locusts. *J Neurophysiol* **91**: 1-12.

3. Integrative mechanisms in small networks of neurons

Natural movements of insects are generated by small networks that are dominated by non-spiking and spiking local interneurons. The role of these interneurons and the integrative mechanisms that underlie the coordinated movements of the legs in walking and jumping, the control of sensory signalling during voluntary movements and the influence of neurosecretory neurons on these networks are being analysed.

Braeunig, P. and **Burrows, M.** (2004).

Projection patterns of posterior dorsal unpaired median neurons of the locust subesophageal ganglion. *J Comp Neurology* **478**: 164-175.

Burrows, M. (1996). The neurobiology of an insect brain. OUP. 696pp.

More information is available on the web:

<http://www.zoo.cam.ac.uk/zoostaff/burrows/index.html>

Processing of auditory signals insects

DR BERTHOLD HEDWIG

The “simple” nervous system of insects offers ideal possibilities to analyse the processing of sensory signals and the generation of motor patterns at the level of identified neuron or small neural assemblies. The research group focuses on acoustically signalling insects, which use auditory signals for communication and are specialists in auditory pattern recognition and orientation. We aim at understanding the neural basis of auditory processing and signal generation and use behavioural studies, neurophysiological approaches and imaging techniques to address some fundamental topics like:

1. The auditory-to-motor interface underlying phonotaxis: How are acoustic signals processed in the nervous system during auditory orientation and steering? What are the neural filters for pattern recognition?
2. The control of singing activity by the central nervous system: Which areas in the brain control singing behaviour and what is the organisation of the central pattern generator for singing?
3. How do the animals deal with the self-generated sounds? An identified interneuron modulates auditory processing during singing. How is this pathway connected to the central pattern generator?

Further information is available on the web:

<http://www.zoo.cam.ac.uk/zoostaff/hedwig/>

Baden, T. and **Hedwig B** (2008)

Front leg movements and tibial motoneurons underlying auditory steering in the cricket (*Gryllus bimaculatus deGeer*).

J. Exp. Biol. 211: 2123-2133.

Baden, T. and **Hedwig, B.** (2007)

Neurite specific Ca²⁺ dynamics underlying sound processing in an auditory interneurone.

J. Neurobiol. 67: 68-80

Hedwig, B. (2006)

Pulses, patterns and paths: neurobiology of acoustic behaviour in crickets.

Comp. Physiol. A. 192: 677-689

Poulet, J.F.A. and **Hedwig, B.** (2006)

The cellular basis of a corollary discharge.

Science 311: 518-522

Hedwig, B. and Poulet, J.F.A. (2004)

Complex behaviour emerges from simple reactive steering.

Nature 430: 781-785.

Mechanisms of Behavioural Plasticity in Locust Swarm Formation

DR S R OTT

When faced with changes in their environment, animals can adjust their morphology, physiology and behaviour to increase their chances of survival. The Desert Locust, notorious for periodic swarms that wreck crops and pastures across Northern Africa, the Middle East and India, provides an extreme example of such phenotypic plasticity. Locusts reversibly change between two very different Phases depending on population density. In their Solitarious Phase, they inhabit barren regions at very low densities, are cryptic in appearance and behaviour, and actively avoid other locusts. Transient rains may permit their numbers to increase but dwindling host plant resources soon force them together in the search for food, and the very proximity to other locusts triggers a radical transformation. After only a few hours, they are highly active and their usual aversion for one another gives way to mutual attraction. Consequently, they aggregate into ever bigger mobile groups. The constant presence of conspecifics then drives slower changes in physiology and morphology and completes the transformation into the swarming Gregarious Phase. Locusts thus provide a powerful model to study fundamental mechanisms of phenotypic plasticity of behaviour. We take an integrative approach that spans multiple levels of biological organization, addressing questions such as:

- what cascades of molecular changes are responsible for the transformation between solitarious and gregarious behaviour?
- to what extent are the behavioural changes consolidated over time?
- where in the nervous system do these molecular changes occur?
- what are the changes in the properties of specific neurones and synapses that alter circuit function to bring about the behavioural changes?
- how are contrasting behavioural demands supported by structural modifications in the sensory and motor systems?

In a recent break-through we have shown that the neurochemical serotonin is both necessary and sufficient for the transition to gregarious behaviour. This creates exciting opportunities for PhD research that can be creatively developed within a clearly defined framework of goals. Training is available in a wide range of techniques including the quantitative analysis of behaviour, pharmacological manipulations and RNA interference, electrophysiology of identified neurons and circuits, laser scanning confocal microscopy, and biochemical and molecular analyses of neural signalling mechanisms.

See also <http://www.zoo.cam.ac.uk/zoostaff/ott.html>

Ott, S.R. and Rogers, S.M. (2010)

Gregarious desert locusts have substantially larger brains with altered proportions compared with the solitarious phase. *Proc R Soc B*, epub ahead of print, <http://dx.doi.org/10.1098/rspb.2010.0694>

Blackburn, L.M., **Ott, S.R.**, Matheson, T., Burrows, M. and Rogers, S.M. (2010)

Motor neurone responses during a postural reflex in solitarious and gregarious desert locusts. *J Insect Physiol*, epub ahead of print, <http://dx.doi.org/10.1016/j.jinsphys.2010.04.011>

Anstey, M.L., Rogers, S.M., **Ott, S.R.**, Burrows, M. and Simpson, S.J. (2009)

Serotonin mediates behavioral gregarization underlying swarm formation in desert locusts. *Science* **323**: 627–30

Ott, S.R., Philippides, A., Elphick, M.R. and O'Shea, M. (2007)

Enhanced fidelity of diffusive nitric oxide signaling by the spatial segregation of source and target neurons in the memory centre of an insect brain. *Eur. J. Neurosci.* **25**: 181–190

The evolution of neurons and neural circuits

DR JEREMY E NIVEN

We are interested in the principles governing the evolution of neural circuits in relation to behaviour. Almost nothing is known about how neural circuits evolve and how this relates to the behaviours they generate. Potentially, almost any aspect of a neural circuit can change influencing behaviour. For example, the number of neurons within a neural circuit, their morphology and physiology and the numbers of connections between neurons could all change. Circuits of identified neurons in insects provide a unique opportunity to assess these changes and relate them to behaviour. Several aspects of this problem are under investigation in our laboratory:

- 1) the tuning of membrane properties in sensory neurons to match environmental stimuli
- 2) the evolution of synaptic connections between identified neurons
- 3) the effects of changes in neural circuits on the behaviours they generate

Our laboratory combines a variety of electrophysiological methods, including intracellular recording and anatomical reconstruction of identified neurons, with behavioural techniques and phylogenetic analysis to approach this problem in insect nervous systems. We encourage students to identify their own PhD projects within this general framework.

More information is available on the web:

<http://www.zoo.cam.ac.uk/zoostaff/niven.htm>

Niven, J.E., Vähäsöyrinki, M., Kauranen, M., Hardie, R.C., Juusola, M. and Weckström, M. (2003). The contribution of *Shaker* K⁺ channels to the information capacity of *Drosophila* photoreceptors. *Nature* **421**: 630-4.

Niven, J.E. and Burrows, M. (2003). Spike width reduction modifies the dynamics of short term depression at a central synapse in the locust. *Journal of Neuroscience* **23**: 7461-9.

Niven, J.E., Anderson, J.C. and Laughlin, S.B. (2007) Fly photoreceptors demonstrate energy-information trade-offs in neural coding. *PLoS Biology* **5**: 828-840.

Niven, J.E. and Laughlin, S.B. (2008). Energy limitation as a selective pressure on the evolution of sensory systems. *Journal of Experimental Biology* **211**: 1792-1804.

The evolution of a neural circuit

DR JEREMY E NIVEN and PROFESSOR MALCOLM BURROWS

What are the principles governing the evolution of neural circuits in relation to behaviour? Almost nothing is known about how neural circuits evolve and how this relates to the behaviours they generate. Potentially, the number of neurones within a neural circuit, the morphology and physiology of those neurones and the numbers of connections between neurones could all change. Circuits of identified neurones in insects provide a unique opportunity to assess these changes and relate them to behaviour. We are in several aspects of this problem:-

- the evolution of a synapse between identified neurones
- the effects of changes in neural circuits on the behaviours they generate
- the evolution of neuromodulatory neurones
- the mechanisms of changing the size of a neurone during evolution

We combining a variety of electrophysiological methods, including intracellular recording and staining of identified neurones, with behavioural techniques and comparative methods to approach this problem.

More information is available on the web:
<http://www.zoo.cam.ac.uk/zoostaff/niven/>

Niven, J.E. and Burrows, M. (2003).
Spike width reduction modifies the dynamics of short term depression at a central synapse in the locust. *J. Neurosci.* **23**: 7461-7469.

Burrows, M. and Wolf, H. (2002).
Jumping and kicking in the false stick insect *Prosarthria teretrirostris*: kinematics and motor control. *J. Exp. Biol.* **205**: 1519-1530.

Burrows, M. (1996).
The Neurobiology of an Insect Brain. Oxford University Press: Oxford.

ANIMAL PHYSIOLOGY

From field studies to detailed laboratory work, animal physiologists investigate biological structure and function in diverse animals. Our research offers a breadth of expertise and in-house training for a wide range of techniques, often focusing on insects as a model system. Research interests include physiological ecology, animal locomotion and biomechanics.

Insect biomechanics and insect-plant interactions

DR WALTER FEDERLE

We study insects and their interactions with plants from a biomechanical perspective. Mechanical factors play a key role in many insect-plant relationships. One mechanical factor fundamental to insect-plant interactions is the insects' capacity to hold on to plant surfaces and to move on them. Many insects combine strong attachment forces with the ability to run. To keep away or trap insects, some plants have developed slippery or sticky surfaces; specialist insects have evolved techniques to circumvent these barriers.

Our current work spans three hierarchical levels, ranging from detailed mechanics to ecological functions:

- Biophysics of insect substrate attachment
- Adaptations to the conflict between attachment and locomotion
- Biomechanics and ecology of specialised insect-plant interactions

We use a variety of methods ranging from force measurement at different size scales, morphometry, interference/fluorescence and electron microscopy, atomic force microscopy and 3D high speed motion analysis. In addition to experimental laboratory work, we study insect-plant interactions in the field in S.E. Asia (Malaysia and Brunei).

More information is available on the web:

<http://www.zoo.cam.ac.uk/zoostaff/federle/index.htm>

Bauer, U., Bohn, H.F. and **Federle, W.** (2008)

Harmless nectar source or deadly trap: *Nepenthes* pitchers are activated by rain, condensation and nectar. *Proc. R. Soc. Lond. B.* **275**: 259-265

Clemente, C. and **Federle, W.** (2008)

Pushing versus pulling: division of labour between tarsal attachment pads in cockroaches. *Proc. R. Soc. Lond. B.* **275**: 1329-1336

Federle, W. (2006)

Why are so many adhesive pads hairy? *J. Exp. Biol.* **209**: 2611-2621

Federle, W. and Endlein, T. (2004)

Locomotion and adhesion: dynamic control of adhesive surface contacts in ants. *Struct. Devel.* **33**: 67-75

Federle, W., Riehle, M., Curtis, A.S.G. and Full, R.J. (2002)

An integrative study on insect adhesion: mechanics and wet adhesion of pretarsal pads in ants. *Int. Comp. Biol.* **42**: 1100-1106

BEHAVIOUR AND BEHAVIOURAL NEUROSCIENCE

Sub-Department of Animal Behaviour, Madingley

Madingley has pioneered the study of behaviour on a number of differing levels, putting together properties that have been isolated for the purpose of experiment, and always having foremost in mind the behaviour of the free living individual. Our levels of investigation include physiological mechanisms; critical periods for learning and memory; social factors influencing learning and the behaviour of social groups of corvids; functional genomics; the mechanisms that generate variation in humans.

Neural mechanisms of learning and memory

DR BRIAN J McCABE

And

PROFESSOR SIR GABRIEL HORN

We are conducting a multidisciplinary research programme, in collaboration with British and foreign colleagues, on the neural mechanisms of learning and memory in vertebrates. A major interest is to analyse the neural basis of imprinting, a type of learning by means of which young animals can recognize objects encountered previously and the role of sleep in this and other types of learning. A wide range of complementary approaches is employed, including behavioural analysis, electrophysiology, molecular biology, *in-situ* hybridisation, immunocytochemistry, computer image analysis, radioligand binding, neurochemistry and computer simulation.

Further information is available on the web:

<http://www.zoo.cam.ac.uk/zoostaff/bneuro.html>

Suge, R., Kato, H. and **McCabe, B.J.** (2010)

Rapid induction of the immediate early gene c-fos in a chick forebrain system involved in memory.
Exp. Brain Res. **200**: 183-188

Jackson, C., **McCabe, B.J.**, Nicol, A.U., Grout, A.S., Brown, M.W. and **Horn, G.** (2008)

Dynamics of a memory trace: effects of sleep on consolidation.
Curr. Biol. **18**: 393-400.

[See also Stickgold R (2008). Sleep: The ebb and flow of memory consolidation. *Curr. Biol.* **18**: R423-R425].

Horn, G. (2004)

Pathways of the past: the imprint of memory.
Nat. Rev. Neurosci. **5**(2): 108-120.

EVOLUTION AND DIVERSITY

In the next decade, our understanding of animal evolution will change more rapidly than at any time in the last century. New fossils, a wealth of molecular data and new approaches to phylogenetic analysis have triggered a resurgence of interest in the history of animal life, and the mechanisms that have generated its present diversity. Comparative morphology, palaeontology, genome sequencing and comparative developmental genetics all have unique contributions to make to this synthesis. We embrace these different disciplines and aim to build bridges between them.

Our palaeontological research emphasises the diversification of Palaeozoic vertebrate groups, the origin of tetrapods from fishes, and the recent development of Quaternary faunas. Arthropods form the current focus for work relating the processes of development and evolution. Projects range from micro-evolutionary studies on closely related species of *Drosophila* to projects that use conserved genes to study the generation of very different body plans. All of this work is supported by, and contributes to, the collections of the University Museum of Zoology.

Segment diversity and the evolution of development in arthropods

PROFESSOR MICHAEL AKAM

Arthropods are among the most diverse of animal phyla, both in terms of morphology and modes of development. We seek to understand how evolutionary changes in the genetic programming of development lead to this diversity. Our current interests focus on the evolution of segmentation and other patterning mechanisms in early development, and the role of *Hox* genes in the control of diverse segment morphologies. We work with *Drosophila* as a reference model system, and with a wide range of other arthropods, including basal insects, crustaceans and myriapods. To provide a context for this work, we also study the pattern of relationship between major groups of arthropods, using molecular phylogenetic methods.

Further information is available on the web:

<http://www.zoo.cam.ac.uk/museum/michael.htm>

Cook, C.E., Yue, Q-Y. and **Akam, M.** (2005)

Mitochondrial genomes suggest that hexapods and crustaceans are mutually paraphyletic.
Proc. Roy. Soc. **272**:1295-1304

Peel, A.D., Chipman, A.D. and **Akam, M.** (2005)

Arthropod segmentation: beyond the *Drosophila* parasigm.
Nature Rev. Genet. **6**:906-916

Chipman, A.D., Arthur, W. and **Akam, M.** (2004)

A double segment periodicity underlies segment generation in centipede development.
Current Biology **14**: 1250-1255

Rozowski, M. and **Akam, M.** (2002)

Hox gene control of segment-specific bristle patterns in *Drosophila*.
Genes. Dev. **16**: 1150-1162

Morphology and interrelationships of living and extinct mammals

DR ROBERT J ASHER

The approximately 5000 species of living mammals are exceedingly diverse. There are mammals that swim, burrow, fly, walk, and hop; and these range in size from an Etruscan shrew (2g) to a blue whale (150 000 000g). Even this diversity falls short of the variability of mammalian clades through geological time, when for example springbok-like hyraxes roamed Eocene Egypt, cow-sized lemurs grazed in Pleistocene Madagascar, or short-necked giraffes made a living in Miocene Spain.

My research focuses on the development and interrelationships of living and extinct mammals. Specific ongoing research projects include the following:

- Skeletodental development and axial skeleton variability in afrotherians and xenarthrans.
- Incorporating diverse types of data (e.g., osteology, vasculature, and DNA) into mammalian phylogeny reconstruction.
- Building a web-based morphological databank for the mammalian skeleton and dentition.
- Understanding how Mesozoic mammals fit into the Tree of Life.

Selected publications:

Asher, R.J., Bennett, N. and Lehmann, T. (2009)

The new framework for understanding placental mammal evolution. *Bioessays* **31**(8):853-864

Asher, R.J. and Olbricht, G. (2009)

Dental ontogeny in *Macroscelides proboscideus* (Afrotheria) and *Erinaceus europaeus* (Lipotyphlis). *Journal of Mammalian Evolution* **16**: 99-115

Asher, R.J. and Lehmann, T. (2008)

Dental eruption in afrotherian mammals. *BMC Biology* **6**:14

Asher, R.J. (2007)

A database of morphologic al characters and a combined-data reanalysis of placental mammal phylogeny. *BMC Evolutionary Biology* **7**:108

Wible, J.W., Rougier, G.W., Novacek, M.J. and **Asher, R.J.** (2007)

Cretaceous Eutherians and Laurasian origin for placental mammals near the K/T border. *Nature* **447**: 1003-1006

Asher, R.J. and Hofreiter, M. (2006)

Tenrecid phylogeny and the non-invasive extraction of nuclear DNA. *Systematic Biology* **55**(2): 181-194.

Asher, R.J., Emry, R.J. and McKenna, M.C. (2005)

New material of Centetodon (Mammalia, Lipotyphla) and the importance of (missing) DNA sequences in systematic paleontology. *Journal of Vertebrate Paleontology* **25**(4): 911-923.

Asher, R.J., Meng, J., Wible, J.R., McKenna, M.C., Rougier, G.W., Dashzeveg, D. and Novacek, M.J. (2005) Stem Lagomorpha and the Antiquity of Glires. *Science* **307** (5712): 1091-1094.

Insects of the tropical rain-forest and oil palm canopy

DR WILLIAM A FOSTER

We are looking at the causes and consequences of the high biodiversity of arthropods in tropical rainforest canopies. Our work has focused on the ecology of the Bird's Nest Fern, which supports a very high density of animals and is an excellent natural microcosm in which to study ecological processes. We are also interested in the role of the arthropods of rainforest fragments in providing ecosystem services in oil-palm plantations and in the general problem of maintaining animal diversity in these plantations. The fieldwork is being carried out at Danum Valley Field Centre in Sabah, East Malaysia.

The kinds of questions we are looking at include:-

- Do rainforest fragments increase arthropod diversity in oil-palm plantations?
- How important are the ferns as reservoirs of biodiversity in the canopy?
- How important are the ferns in the ecology of degraded ecosystems, such as logged forest and oil-palm plantations?
- What factors affect animal biodiversity within the ferns?

More information is available on the web:

<http://www.zoo.cam.ac.uk/zoostaff/foster/research.html>

Fayle, T.M., Turner, E.C., Snaddon, J.L., Chey, V.K., Chung, A.Y., Eggleton, P.E. & **Foster, W.A.** (2010). Oil palm expansion into rain forest greatly reduces ant biodiversity in canopy, epiphytes and leaf litter. *Basic and Applied Ecology* **11**: 337-345.

Ellwood, M.D.F., Manica, A. and **Foster, W.A.** (2009) Stochastic and deterministic processes jointly structure tropical arthropod communities. *Ecology Letters* **12**: 1-8

Turner, E.C. and **Foster, W.A.** (2009) The impact of forest conversion to oil palm on arthropod abundance and biomass in Sabah, Malaysia. *Journal of Tropical Ecology* **25**: 23-30

Turner, E.C., Snaddon, J.L., Fayle, T.M. and **Foster, W.A.** (2008) Oil palm research in context: indentifying the need for biodiversity assessment. *PLOS ONE* **3**: e1572

Ellwood, M.D.F. and **Foster, W.A.** (2004) Doubling the estimate of invertebrate biomass in a rainforest canopy. *Nature* **429**: 549-551

The evolution of pattern diversity in tropical butterflies

DR CHRISTOPHER D JIGGINS

Our work addresses the origins of biodiversity using tropical butterflies as a model system. Specific areas of research could include:-

- a) the application of genomics techniques to study the genetic basis of colour pattern evolution, using linkage mapping and gene expression studies to identify the genes underlying colour pattern diversity. Techniques include EST sequencing and population genetic studies to identify candidate genes and study patterns of variation under selection, and evolutionary developmental biology (evo-devo) to study expression patterns of candidate loci;
- b) bioinformatic approaches to understanding genome evolution in the Lepidoptera including studies of evolutionary rates across the genome and patterns of synteny, taking advantage of the imminent sequencing of the *Heliconius melpomene* genome;
- b) behavioural studies of mate preferences between races and species of *Heliconius* to investigate the role of colour pattern in speciation

This project offers the opportunity to combine modern molecular genetics with fieldwork and behavioural studies in tropical America. I encourage interested applicants to get in touch to discuss specific details or areas of interest – please contact me by email for more information (see <http://www.heliconius.org>)

More information is available on the web:

http://heliconius.zoo.cam.ac.uk/all_opportunities/

Joron, M., Papa, R., Beltrán, M., Chamberlain, N., Mavárez, J., Baxter, S., Bermingham, E., Humphray, S., Rogers, J., Beasley, H., Barlow, K., French-Constant, R., Mallet, J., McMillan, W.O. and **Jiggins, C.D.** (2006)

A Conserved Supergene Locus Controls Colour Pattern Diversity in *Heliconius* Butterflies.
Plos Biology. Vol. 4: e303.

Mavárez, J., Salazar, C., Bermingham, E., Salcedo, C., **Jiggins, C.D.** and Linares, M. (2005)
Speciation by hybridization in *Heliconius* butterflies.
Nature 441: 868-871

Jiggins, C.D., Naisbit, R.E., Coe, R.L. and Mallet, J. (2001)
Reproductive isolation caused by colour pattern mimicry.
Nature (London) 411: 302-305

Beltrán, M., **Jiggins, C.D.**, Bull, V., McMillan, W.O., Bermingham, E. and Mallet, J. (2002)
Phylogenetic discordance at the species boundary: gene genealogies in *Heliconius* butterflies.
Molecular Biology and Evolution 19: 2176-2190

Estrada, C. and **Jiggins, C.D.** (2002)
Patterns of pollen feeding and habitat preference among *Heliconius* species.
Ecological Entomology 27: 448-456

Adaptive evolutionary genetics of vertebrates

DR NICHOLAS I MUNDY

What are the genetic changes underlying adaptation? This fundamental question has been a difficult one to answer, but a combination of modern molecular genetic methods and choice of appropriate phenotypes is now making it tractable. Our current research focuses on the molecular basis of adaptive evolution in coloration, and the brain and sensory systems of vertebrates. We are increasingly adopting genomic approaches to address these questions, and developing novel methods of rigorously testing for associations between genotypic and phenotypic evolution.

Current research projects include:-

- Genetic basis of coloration in primates, birds and frogs
- Genetic basis of primate brain expansions
- New methods for detecting genotype-phenotype associations

Further information is available on the web:

<http://www.zoo.cam.ac.uk/zoostaff/egg/Index.htm>

Montgomery, S.H., Capellini, I., Barton, R.A. and **Mundy, N.I.** (2010)

The ups and downs of primate brain evolution: implications for adaptive hypotheses and *Homo floresiensis*. *BMC Biology* **8**: 9

Bradley, B. J. and **N. I. Mundy** (2008) The primate palette: the evolution of primate coloration. *Evolutionary Anthropology* **17**, 97-111.

Nadeau, N.J., Burke, T.A. and **Mundy, N.I.** (2007)

Evolution of an avian pigmentation gene correlates with a measure of sexual selection. *Proc. Roy. Lond. B.* **274**: 1807-1813

Mundy, N.I., Badcock, N., Hart, T., Scribner, K., Janssen, K. and Nadeau, N.J. (2004)

Conserved genetic basis of a quantitative plumage trait involved in mate choice. *Science* **303**: 1870-1873

Quaternary Ecology

DR RICHARD PREECE

Collaborative work with other departments involves detailed biostratigraphical analyses of sediment samples with a view to documenting changing plant and animal (principally land snail) successions. A chronology of these changes can be provided by means of radiocarbon dating. The kinds of questions we are addressing include:-

- Are these changes purely responses to climatic oscillations or are they governed by other factors?
- Do changes in different groups of organisms coincide or are they out of phase?
- How rapidly do these changes occur and are the same patterns observable at all sites?

Preece, R.C. and Day, S.P. (1994).

Comparison of post-glacial molluscan and vegetational successions from a radiocarbon-dated tufa sequence in Oxfordshire.

J. Biogeogr. **21**: 463-478

Preece, R.C. and Bridgland, D.R. (1999).

Holywell Coombe, Folkestone: a 13,000 year history of an English Chalkland Valley.

Quat. Sci. Rev. **18**: 1075-1125

BEHAVIOURAL ECOLOGY

Our research interests range from studies of the strategies used by individuals to compete for resources (food, mates, territories) to how conflicts among individuals and ecological conditions combine to influence breeding systems, population dynamics and community structure. Current studies include fieldwork on mammals, birds and insects, theoretical studies of signalling behaviour and molecular genetic work on breeding systems. The Ecology Group comprises eight academic staff, twenty post-doctoral research fellows and thirty-five PhD students. We have weekly seminars and regular lunch-time discussions.

Behavioural Ecology

PROFESSOR NICHOLAS B DAVIES

Students are encouraged to suggest their own ideas for research. There are excellent facilities for fieldwork locally, in the surrounding fenland and also opportunities to work abroad. Recent studies include:-

- **Mating systems.** Field observations and experiments on behaviour, combined with DNA profiles to measure individual reproductive success, in polyandrous dunnocks, alpine accentors (Pyrénées), and jacanas (Southern India) and of Australian fruit bats.
- **Cooperative breeding.** The role of ecological factors and conflicts between breeders and helpers in moorhens, mesites (Madagascar), woodhoopoes (South Africa) and babblers (Australia).
- **Brood parasites and their hosts.** Experimental studies of cuckoo-host coevolution in Britain, Namibia and South Africa, of cowbirds and their hosts in Argentina and Costa Rica.
- **Sexual selection.** Studies of colour and display in *Agama* lizards on Mediterranean islands, with reference to species isolation.
- **Life histories.** Brood reduction and the influence of age on reproductive success in blackbirds.
- **Communication.** Parent-offspring communication in reed warblers and other cuckoo hosts, and its exploitation by cuckoos. Deceptive alarm signals by drongos used in kleptoparasitism (South Africa). Family conflicts in hornbills (South Africa).

Further information is available on the web:

<http://www.zoo.cam.ac.uk/zoostaff/bbe/index.htm>

Davies, N.B. (2000)

Cuckoos, Cowbirds and Other Cheats. (T and A D Poyser).

Davies, N.B. *et al.* (2006)

A host-race of the cuckoo, *Cuculus canorus*, with nestlings attuned to the parental alarms of the host species. *Proc.Roy.Soc.B*.**273**:693-699

Welbergen, J.A. and **Davies, N.B.** (2009)

Strategic variation in mobbing as a front line of defence against brood parasitism.

Current Biology **19**: 235-40

Davies, N.B. and Welbergen, J.A. (2009)

Social transmission of a host defence against cuckoo parasitism.

Science **324**: 1318-24.

Behavioural Ecology

PROFESSOR TIMOTHY H CLUTTON-BROCK

Research in my group focuses on the evolutionary causes and ecological consequences of variation in animal breeding systems. We work with a wide range of animals, including insects, fish and, especially, mammals. Several studies based here use established field sites in Scotland and on the islands of Rum (red deer) and St Kilda (Soay sheep), as well as in Uganda (banded mongoose) and South Africa (meerkats), where we are able to recognise large samples of individuals and have monitored their growth and breeding success from birth.

Students are encouraged to suggest their own ideas for research, either on our established study populations or on species of their choice.

Recent studies include:-

- Parental strategies - recent research has explored the evolution of male versus female parental care (in assassin bugs, rheas and cichlid fish); the division of parental investment among offspring and the cost of rearing sons and daughters; adaptive strategies of sex ratio variation, and the resolution of conflicts of interest between parents and young.
- Co-operative breeding - projects in Uganda and South Africa are currently exploring the evolution of co-operative breeding in social mongooses, focusing on the division of labour among helpers and reproductives and the hormonal controls of cooperative behaviour.
- Coercion, punishment, feuding and reconciliation - theoretical work has explored the evolution of complex social interactions between group members, concentrating on patterns of interaction commonly observed in primates. Empirical work has investigated the costs of sexual coercion.
- The effects of breeding systems on population dynamics - recent work has explored the consequences of contrasts in breeding systems for population regulation and stability, using long-term demographic records for contrasting systems.
- Sexual selection and population dynamics - research on red deer and Soay sheep (using DNA analysis) has examined the extent to which changes in population density affect the distribution of male success, the intensity of sexual selection and the heritability of fitness through the male line. Theoretical work has investigated the factors controlling the relative intensity of competition for mates in the two sexes.
- Immigration, emigration and the frequency of inbreeding - long-term studies of red deer, sheep and meerkats have explored the ecological causes and evolutionary consequences of emigration and the frequency of inbreeding.

Further information on possible projects is available on the web:

<http://www.zoo.cam.ac.uk/zoostaff/larg/pages/index.html>

Clutton-Brock, T.H., Coulson, T.N., Milner-Gulland, E.J., Thomson, D. and Armstrong, H. (2002) Sex differences in emigration and mortality affect optimal management of deer populations. *Nature* **415**: 633-637

Clutton-Brock, T.H., Brotherton, P.N.M., O'Riain, M.J., Russell, A.F., Gaynor, D., Kansky, R., Griffin, A., Manser, M., Sharpe, L., McIlrath, G.M., Small, T., Moss, A. and Montfort, S. (2001) Cooperation, conflict and concession in meerkat groups. *Science* **291**: 478-481

Clutton-Brock, T.H., Russell, A.F., Brotherton, P.N.M., Sharpe, L., McIlrath, G.M., White, S. and Cameron, E.Z. (2001) Effects of helpers on juvenile development and survival in meerkats. *Science* **293**: 2446-2449

Clutton-Brock, T.H., O'Riain, M.J., Brotherton, P.N.M., Gaynor, D. and Kansky, R. (1999) Selfish sentinels in co-operative mammals. *Science* **284**: 1640-1644

The Evolution of Family Life

DR REBECCA M KILNER

Our research focuses on social evolution, animal communication and co-evolution and uses animal families as model systems for experimental analysis. We study conflict, cooperation and communication in several different bird species including local blackbird, blue tit and great tit populations in Britain and the Hihi (or Stitchbird) in New Zealand. Most of our work on co-evolution examines the interactions between the Australian *Chalcites* cuckoos and their hosts. Our most recent work on social evolution focuses on burying beetles in the laboratory and in the field near Cambridge. □ Burying beetles raise their young on the flesh of a dead vertebrate and protect the carcass from microbial rivals by smearing the flesh with anti-bacterial exudates. We are currently investigating how adults cooperate to mount this social immune response.

We encourage prospective students to devise their own research projects, but we are happy to provide specific guidance as well.

Recent PhD students have worked on:-

- **The evolution and design of animal signals:** by using field experiments and comparative analyses to explain variation among individuals and among species in the design of the nestling begging display
- **Maternal effects:** by using field experiments and hormonal analyses to investigate how investment in the egg influences subsequent conflicts of interest in the family
- **Conflicts of interest within the family:** by using field experiments to determine how parent-offspring conflict and sexual conflict are resolved
- **Ageing:** by using laboratory experiments on burying beetles to determine how developmental conditions influence lifespan, and to identify sex differences in patterns of senescence

Further information is available on the web:

<http://www.zoo.cam.ac.uk/zoostaff/bbe/Index.htm>

Langmore, N.E., Hunt, S. and **Kilner, R.M.** (2003)
Escalation of a co-evolutionary arms race through host rejection of brood parasitic young.
Nature **422**: 157-160

Kilner, R.M., Madden, J.R. and Hauber, M.E. (2004)
Brood parasitic cowbirds use host young to procure resources.
Science **305**: 877-879

Russell, A.F., Langmore, N.E., Cockburn, A., Astheimer, L.B. and **Kilner, R.M.** (2007)
Reduced egg investment can conceal helper effects in cooperatively breeding birds.
Science **317**: 941-944

Hinde, C.A., Johnstone, R. A. and **Kilner, R.M.** (2010)
Parent-offspring conflict and co-adaptation.
Science **327**: 1373-1376

Cotter, S. C., Topham, E., Price, A. J. P. and **Kilner, R. M.** (2010)
Fitness costs associated with mounting a social immune response.
Ecology Letters doi: 10.1111/j.1461-0248.2010.01500.x

Sensory Ecology, Animal Signals, and Behaviour

DR MARTIN STEVENS

My research spans several subject areas, but most notably animal coloration, visual perception, and behaviour. I use a range of study systems to investigate the evolution of visual signalling, including anti-predator coloration (camouflage, warning coloration, eyespots), brood parasitism, and mate choice. I am also interested in developing new techniques to study vision and visual signals. My research often makes links with aspects of experimental psychology and computer vision.

Work can be field based (UK and abroad), lab based, or both, and a mixture of experimental and modelling approaches. I am happy for students to suggest ideas for research projects, but current areas of interest include:

- Arms races, visual signalling, and brood parasitism, including egg mimicry and chick coloration
- Animal camouflage, including how this is optimised under different conditions and the visual mechanisms involved
- Multifunctional signals – how animals use the same pattern to achieve multiple functions (e.g. combining camouflage, warning signals, sexually selected signals)
- Interactions between behaviour and visual signals
- The relationship between animal coloration and the visual system(s) of the principal receiver(s)

Further information is available on the web:

<http://www.zoo.cam.ac.uk/zoostaff/bbe/Stevens/Martin1.htm>

Spottiswoode, C.N. & **Stevens, M.** (2010).

Visual modeling shows that avian host parents use multiple visual cues in rejecting parasitic eggs. *Proceedings of the National Academy of Sciences of the USA*. **107**: 8672-8676

Stoddard, M.C. & **Stevens, M.** (2010).

Pattern mimicry of host eggs by the common cuckoo, as seen through a bird's eye. *Proceedings of the Royal Society, Series B*. **277**: 1387–1393.

Stevens, M., Yule, D. H. & Ruxton, G. D. (2008).

Dazzle coloration and prey movement. *Proceedings of the Royal Society, Series B*. **275**: 2639–2643.

Stevens, M., Hardman, C. J., & Stubbins, C. L. (2008).

Conspicuousness, not eye mimicry, makes 'eyespots' effective anti-predator signals. *Behavioral Ecology*. **19**: 525–531.

Stevens, M. & Cuthill, I. C. (2007).

Hidden Messages: Are Ultraviolet Signals a Special Channel in Avian Communication? *BioScience*. **57**: 501-507.

Cuthill, I. C., **Stevens, M.**, Sheppard, J, Maddocks, T, Párraga, C. A. & Troscianko, T. (2005).

Disruptive coloration and background pattern matching. *Nature*. **434**: 72-74.

Modelling in behavioural ecology: conflict, co-operation and communication

DR RUFUS A JOHNSTONE

My research involves the use of optimality modelling and game theory to predict how animals behave under different social and ecological conditions.

Particular areas of interest include:-

- Communication and the design of animal signals (including sexual signalling, dominance display, communication between parents and offspring and mimicry).
- Sexual conflict and mate choice (including the tactics of choice, sex differences in mating behaviour and the evolution of sexual coercion and manipulation).
- Conflict and co-operation in social groups (including reproductive skew, dominance testing and eavesdropping).

Further information is available on the web:

<http://www.zoo.cam.ac.uk/zoostaff/beg/index.html>

Johnstone, R.A. (2002)

The evolution of inaccurate mimics. *Nature* **418**: 524-526

Johnstone, R.A. (2004)

Begging and sibling competition: how should offspring respond to their rivals? *Am. Nat.* **163**: 388-406

Johnstone, R.A. and Hinde, C.A. (2006)

Negotiation over offspring care: how should parents respond to each others' efforts.

Behav. Ecol. **17**: 818-827

Johnstone, R.A. (2008)

Kin selection, local competition and reproductive skew. *Evolution* **62**: 2592-2599

Hinde, C.A., **Johnstone, R.A.** and Kilner, R.M. (2010)

Parent-offspring conflict and co-adaptation. *Science* **327**: 1373-1376

Behavioural Ecology

DR ANDREA MANICA

My research focuses on understanding the causes, patterns and consequences of animal movement. Currently, I mostly work on the solution of conflicts in groups of individuals for which coordination is beneficial. Using sticklebacks as a model system, we have been able to show that personality plays an important role in the emergence of leaders and followers within pairs of foraging individuals. Taking advantage of a new analytical framework we developed, we were able to infer the exact rules that individuals use to respond to each others' behaviour and showed that leadership is the result of social feedback, with strong leaders inspiring faithful followership and good followers improving the initiative of their leaders. We now plan to look at more complicated coordination problems, and this topic would be very suitable as a PhD project.

Further information is available on the web:

<http://www.zoo.cam.ac.uk/zoostaff/manica/index.htm>

Harcourt, J.L., Sweetman, G., **Manica, A.** and Johnstone, R.A. (2010)

Pairs of fish resolve conflicts over coordinated movement by taking turns. *Curr. Biol.* **20**: 156-160

Harcourt, J.L., Ang, T.Z., Sweetman, G., Johnstone, R.A. and **Manica, A.** (2009)

Social feedback and the emergence of leaders and followers. *Current Biology* **19**: 248-252

Harcourt, J.L., Sweetman, G., Johnstone, R.A. and **Manica, A.** (2009)

Personality counts: the effect of boldness on shoal choice in a three-spined stickleback.

Animal Behaviour **77**: 1501-1505

CONSERVATION BIOLOGY

Conservation Biology strives to supply biological answers to questions of why, what, where and how to conserve. The quality and relevance of our research in this area is enhanced by the Department's strong links with conservation organisations based in and around Cambridge (including the RSPB, BirdLife International, the World Conservation Monitoring Centre, Fauna and Flora International, the Tropical Biology Association and Natural England). We maintain close relationships with conservation biology groups across the UK and beyond by hosting the annual Student Conference on Conservation Science.

Conservation Biology

PROFESSOR WILLIAM J SUTHERLAND

I greatly welcome applications from students from the UK and across the globe interested in studying conservation problems. Most of our research has been on birds but we have sometimes extended our approaches to study other groups.

Current potential areas for research in the UK include predicting the consequences of changing agricultural practices upon biodiversity in the UK, examining how evidence is used by conservation practitioners and how research could be combined with conservation practice.

I welcome projects from overseas that include a proposal for research that either examines the conservation problems of specific species or general conservation issues. However, I do not currently have sources of funding for these so they will require external funding.

Projects that strengthen links with any of the numerous conservation organisations in the Cambridge area (see www.cambridgeconservationforum.org.uk) are very welcome, as also are those that combine disciplines.

My main research areas are:

Researching conservation problems

Previous students have studied a wide range of applied problems affecting birds, such as the impact of human disturbance, agricultural change, climate change, coffee production methods, tropical forest loss and the impact of fire.

Catry, I., Franco, A.M.A. and **Sutherland, W.J.** (2009)

Identifying the effectiveness and constraints of conservation interventions: a case study of the endangered lesser kestrel. *Biological Conservation* **142**: 2782-2791

Predicting the impact of environmental change

The objective has been to explore ways of quantifying the impact of habitat change on bird populations. This has usually involved detailed field studies of the ecology of a particular species or the impact of a particular conservation issue. Where possible we then devise predictive models. We have applied this approach to consider a wide range of issues including the impact of disturbance, GM crops, habitat loss and agricultural change.

Sutherland, W.J. (2006) Predicting the ecological consequences of environmental change: a review of the methods. *Journal of Applied Ecology* **43**: 599-616

Evidence-based conservation

Medicine has undergone a revolution as a result of the collation and assessment of evidence on the effectiveness of management. We coordinate the website www.conservationevidence.com with the objective of improving the access of information on the effectiveness of conservation. I am currently very interested in researching how practitioners use and collate evidence, the constraints upon them, the gains of using evidence and what would enable the collation and use of evidence to become routine practice. This could be carried out in conjunction with research on the effectiveness of given conservation practices.

Sutherland, W.J., Pullin, A.S., Dolman, P.M. and Knight, T.M. (2004)
The need for evidence-based conservation.
Trends in Ecology and Evolution 19: 305-308

Population biology

As well as working on direct conservation problems we have been heavily involved in understanding population ecology and especially in deriving population models from the first principles of behavioural ecology.

Sutherland, W.J. (2005)
From Individual Behaviour to Population Ecology.
OUP.

Further information is available on the web:
<http://www.zoo.cam.ac.uk/zoostaff/csg/sutherland.htm>

If interested, please contact me by email at w.sutherland@zoo.cam.ac.uk, sending a c.v. and an outline of a project that you would be interested in carrying out.

Conservation Science

PROFESSOR ANDREW BALMFORD

I work closely with conservation organisations based in Cambridge and beyond (including RSPB, the UNEP-World Conservation Monitoring Centre and WWF-US), and am increasingly involved with colleagues in the social, as well as natural, sciences

My current interests focus on three main topics:

- the costs and benefits of conservation, with work on ecosystem services globally and in Tanzania;
- the question of how best to reconcile conservation and the rising demand for food production, where I'm especially interested in the trade-off between wildlife-friendly farming and land-sparing through agricultural intensification;
- enhancing conservation effectiveness through measuring the impact of interventions, and increasing public support for saving wild nature.

In all research areas, students are strongly encouraged to develop their own research ideas.

For more information about our Group and some recent references, visit <http://www.zoo.cam.ac.uk/zoostaff/csg/index.html>

Conservation Biology

PROFESSOR RHYS GREEN

I study the scientific basis for the conservation of threatened animal populations and the impacts of climate and land use change on their status. Topics include modelling of changes of distribution and abundance in relation to climatic and land use change, studies of effects of food and habitat selection and population processes and assessments of the effects of conservation management on demographic rates. Study organisms are mostly birds.

Further information is available on the web:
<http://www.zoo.cam.ac.uk/zoostaff/Green.htm>

Gregory R.D. *et al* (2009)
An Indicator of the Impact of Climatic Change on European Bird Populations.
PLoS ONE **4**, e4678.

Green, R.E. *et al* (2008) Effectiveness of Action to Reduce Exposure of Free-Ranging California Condors in Arizona and Utah to Lead from Spent Ammunition.
PLoS ONE **3**, e4022. doi:10.1371/journal.pone.0004022

Green, R.E. *et al* (2005)
Farming and the fate of wild nature.
Science **307**: 550-555

Conservation Biology of Birds

DR MICHAEL de L BROOKE

My conservation work complements my position as Curator of Birds in the University Museum of Zoology and includes both practical and theoretical research, targeting conservation planning. Current research students are studying impacts of climate change on the distribution of North American birds and why endangered bird species show mate-biased sex ratios.

Islands: I am involved with programmes to remove alien species from oceanic islands, in conjunction with UK Overseas Territories Conservation Forum and RSPB. A collaborative study with the RSPB has investigated how such programmes might be prioritised at a worldwide level. There may now be scope for modifying the protocol to address regional prioritisation. Funded by the Foreign Office, London, I am also involved in assessing the feasibility of eradicating rats from Henderson Island, a World Heritage Site in the South Pacific. An ongoing fieldwork project is studying the population dynamics of the critically threatened Raso Lark, a critically endangered single-island endemic in the Cape Verdes. In the long term, we hope to establish a second population on another island besides Raso.

Seabirds: Seabirds are taxonomically complex, probably due to extreme philopatry and post-Pleistocene range ability. Resolution of the phylogenetic uncertainty will allow conservation resources to be more specifically targeted.

Bird Plumage: While some aspects of bird plumage are related to sexual selection, we lack a general predictive framework for bird coloration. I am investigating alternative explanations of bird colours. A recent research student studied the occurrence of black-brown sexual dimorphism among passerine birds.

Students who might wish to join our group are welcome to suggest their own projects that may fit, more or less precisely, into the above areas.

More information is available on the web:

http://www.zoo.cam.ac.uk/museum/mike_b.htm

<http://www.zoo.cam.ac.uk/zoostaff/bbe/index.htm>

Brooke, M. de L., Hilton, G.M. and Martins, T.L.F. (2007)
Prioritising the world's islands for vertebrate eradication programmes.
Anim. Cons. **10**: 380-390

Martins, T.L.F., **Brooke, M. de L.**, Hilton, G.M., Farnsworth, S., Gould, J. and Pain, D.J. (2006)
Costing eradications of alien mammals from islands.
Anim. Cons. **9**: 439-444

Brooke, M de L. (2004)
Albatrosses and petrels across the world. OUP, Oxford

Burg, T.M., Almond, R., Lomax, J., **Brooke, M de L.** and Amos, W. (2003)
Unravelling dispersal patterns in an expanding population of a highly mobile seabird, the Northern Fulmar.
Proc. Roy. Soc. B. **270**: 979-984

Brooke, M de L. (2001)
Systematics and distribution of seabirds of the world: a review of current knowledge.
pp 57-83 in "The Biology of Marine Birds" (Ed. E-A Schreiber & J Berger). CRC Press, Boca Raton.

POPULATION AND COMMUNITY ECOLOGY

Ecological research in the department is a diverse mixture of pure and applied work, using both theoretical and empirical methods. It ranges across the nonlinear spatial dynamics and control of infectious diseases, freshwater community ecology, the population dynamics of mammals and the molecular ecology of a number of groups, notably marine mammals, insects and parasites.

Population Dynamics and Selection

PROFESSOR TIMOTHY H CLUTTON-BROCK

Research based in my group is investigating the population dynamics of mammals and the effects of variation in population density on selection.

In particular, we are interested in the ways in which variation in breeding systems affects population dynamics and stability. Our research in this area mostly uses populations of ungulates (red deer and Soay sheep) in the Hebrides for which long-term records of population size and individual life-histories are available.

In addition, we are interested in the causes and consequences of Allee effects in social mammals, while studies of African mammals have explored the impact of human populations on reproduction, survival and population density.

Potential students are encouraged to suggest their own projects, either using our long-term study populations, or on other species.

More information is available on the web:

<http://www.zoo.cam.ac.uk/zoostaff/larg/pages/index.html>

Clutton-Brock, T.H. et al. (1997)

Stability and instability in ungulate populations: an empirical analysis.

Am. Nat. **194**: 195-219

Courchamp, F., Grenfell, B.T. and **Clutton-Brock, T.H.** (2000)

Impact of natural enemies on obligately cooperative breeders.

Oikos **91**: 311-322

Coulson, T.N., Catchpole, E.A., Albon, S.D., Morgan, B.J.T., Grenfell, B.T. and **Clutton-Brock, T.H.** (2000)

Age, sex, density, winter weather and population crashes in Soay sheep.

Science **292**: 1528-1531

Clutton-Brock, T.H., Coulson, T.N., Milner-Gulland, E.J., Thomson, D. and Armstrong, H. (2002)

Sex differences in emigration and mortality affect optimal management of deer populations.

Nature **415**: 633-637

Population Genetics

DR ANDREA MANICA

I am interested in understanding the patterns of movement of individuals among populations. The genetic signature left by such movements can be used to reconstruct the history of how population networks have formed (the historical demography of a metapopulation). Humans provide large scale datasets, ideal for this sort of question, and over the last few years we have worked to model the process by which anatomically modern humans migrated out of Africa 50,000 years ago to colonise the whole world. The rapid spread into new, previously uninhabited lands was characterised by a series of bottlenecks (founder effects) which led to a gradual loss of genetic and phenotypic diversity the further one moves away from the African origin. Reconstructing this process not only tells us something about the origin of a species but is also fundamental in removing confounding patterns that prevent the meaningful comparison of the effect of selection in different populations.

Further information is available on the web:

<http://www.zoo.cam.ac.uk/zoostaff/manica/index.htm>

Betti, L., Balloux, F., Amos, W., Hanihara, T. and **Manica, A.** (2009)

Distance from Africa, not climate, explains within-population phenotypic diversity in humans.
Proc. Roy. Soc. Lond. B. **276**: 809-814

Manica, A., Amos, W., Balloux, F. and Hanihara, T. (2007)

The effect of ancient population bottlenecks on human phenotypic variation.
Nature **448**: 346-348

Linz, B., Balloux, F., Moodley, Y., **Manica, A.** et al. (2007)

An African origin for the intimate association between humans and *Helicobacter pylori*.
Nature **445**: 915-918

Molecular Ecology

PROFESSOR BILL AMOS

Molecular genetic techniques are proving powerful tools for determining relatedness at many different levels, from individuals within a population up to species and higher taxonomic groups, giving insights into breeding behaviour, social organisation, population structure and taxonomy. Applied to natural populations, these techniques allow us to ask fundamental questions in a range of disciplines from behavioural ecology and evolution through to epidemiology and conservation biology. My current research interests focus on:

- the evolution of the marker DNA sequences themselves, particularly microsatellites
- the evolution of the Y-chromosome and its use in resolving population structure and population history
- questions relating to breeding behaviour and population structure in marine mammals
- developing new methods for gene mapping
- the relationship between heterozygosity and fitness
- application of methods such as Markov chain Monte Carlo to problems in evolutionary biology

Further information is available on the web:

<http://www.zoo.cam.ac.uk/zoostaff/amos/>

Amos, W., Worthington Wilmer, J. and Kokko, H. (2001)
Do female grey seals select genetically diverse mates?
Anim. Behav. **62**: 157-164

Gaggiotti, O.E., Jones, F., **Amos, W.**, Harwood, J. and Nichols, R.A. (2002)
Patterns of colonisation in a grey seal metapopulation.
Nature **416**: 424-427

Acevedo-Whitehouse, K., Gulland, F., Greig, D. and **Amos, W.** (2003)
Inbreeding-dependent pathogen susceptibility in California sea lions.
Nature **422**: 35

Amos, W. and Harwood, J. (1998)
Factors affecting levels of genetic diversity in natural populations.
Phil. Trans. Roy. Soc. B. **353**: 1-12

Amos, W., Worthington-Wilmer, J., Fullard, K., Burg, T.M., Croxall, J.P., Bloch, D. and Coulson, T.N. (2001)
The influence of parental relatedness on reproductive success.
Proc. Roy. Soc. Lond. B. **268**: 2021-2027

Pathogen Evolution

PROFESSOR DEREK J SMITH

Our research focuses on the co-evolutionary and population dynamics of antigenically variable pathogens. We have developed a method, antigenic cartography, which for the first time allows one to quantify phenotypic differences among pathogen strains. This method was developed on influenza viruses, and much of our research focuses on influenza viruses; however, the method is generic and is also being applied to other antigenically variable pathogens.

Our work is a combination of computational, mathematical, theoretical, and experimental. Much of the experimental work is done by our primary collaborator Professor Ron Fouchier at Erasmus Medical Centre. Our groups are tightly integrated and see no discipline boundaries, and we very much expect new group members to be the same way - not that mathematicians need to work in a wet lab, but they do need to be able to communicate effectively with wet biologists, and vice-versa.

In addition to fundamental research, our work also has direct application to public and animal health, and we consider this a very important aspect of our work. For example, we analyze the full data generated by the World Health Organization global influenza surveillance program, and I sit on the committee at the WHO that, every six months, selects the strains of influenza virus used in the human influenza vaccine. Particularly in the case of influenza viruses, there is a tremendous synergy between public health and fundamental research.

Particular areas of interest include:

- The coevolution of pathogens with immunity in the population
- The molecular determinants of antigenic evolution
- The population dynamics of antigenically variable pathogens
- The within-host immune response to repeated exposure to antigenic variants

Further information is available on the web:

<http://www.zoo.cam.ac.uk/zoostaff/smithd.html>

Garten, R. *et al* (2009)

Antigenic and genetic characteristics of swine-origin 2009 (H1N1) influenza viruses circulating in humans.

Science **325**: 197-201

Russell, C.A. *et al* (2008)

The global circulation of seasonal influenza A (H3N2) viruses.

Science, **320**: 340-346

Smith, D.J. (2006)

Predictability and preparedness in influenza control.

Science **312**: 392-394

Smith, D.J., Lapedes, A.S., de Jong, J.C., Bestebroer, T.M., Rimmelzwaan, G.F., Osterhaus, A.D.M.E. and Fouchier, R.A.M. (2004)

Mapping the Antigenic and Genetic Evolution of Influenza Virus.

Science **305**: 371-376

Smith, D.J., Forrest, S., Ackley, D.H. and Perelson, A.S. (1999)

Variable Efficacy of Repeated Annual Influenza Vaccination.

Proc. Natl. Acad. Sci. **96**: 14001-14006

Aquatic Ecology

DR DAVID C ALDRIDGE

We study a wide range of topics in the ecology of freshwater communities, from the impacts of river management to the applied use of freshwater organisms in biomanipulation, environmental monitoring and the prediction and control of invasive species. Much of our work focuses on conservation of freshwater animals and this often requires a full analysis of ecosystem interactions. Our research is primarily carried out in waterways throughout Britain, although we also have projects running in China, Colombia, USA, Bangladesh and New Zealand. The applied nature of our work results in many studentships being supported by industrial CASE partners.

Current projects include:-

- The prediction of invasive species in European freshwaters
- Control of invasive filter feeders using microencapsulated BioBullets
- The role of freshwater mussels in aquatic ecosystems
- The conservation of the Depressed River Mussel, *Pseudanodonta complanata*.
- Minimising the impact of river management on conservation and biodiversity.
- Conservation and habitat restoration in China's lakes.
- Biology and control of industrial biofoulers

More information can be found on the web at:-

<http://www.zoo.cam.ac.uk/zoostaff/aldridge/index.html>

Oreska, M.P.J. and **Aldridge, D.C.** (2010)

Estimating the financial costs of freshwater invasive species in Great Britain: a standardized approach to invasive species costing.

Biological Invasions (Online early)

Zieritz, A., Hoffman, J.I., Amos, W. and **Aldridge, D.C.** (2010)

[Phenotypic plasticity and genetic isolation-by-distance in the freshwater mussel *Unio pictorum* \(Mollusca: Unionoida\)](#)

Evolutionary Ecology **24**, 923-938

Keller, R.P., Ermgassen, P.S.E.Z. and **Aldridge, D.C.** (2009)

[Vectors and Timing of Freshwater Invasions in Great Britain](#)

Conservation Biology **23**, 1526-1534

Sousa, R., Gutierrez, J.L. and **Aldridge, D.C.** (2009)

[Non-indigenous invasive bivalves as ecosystem engineers.](#)

Biological Invasions **11**, 2367-2385

Aldridge, D.C., Salazar, M., Serna, A. and Cock, J. (2008)
[Density-dependent effects of a new invasive false mussel, *Mytilopsis trautwineana* \(Tryon 1866\), on shrimp, *Litopenaeus vannamei* \(Boone 1931\), aquaculture in Colombia](#)
Aquaculture **281**, 34-42

Costa, R., **Aldridge, D.C.** and Moggridge, G.D. (2008)
[Seasonal variation of zebra mussel susceptibility to molluscicidal agents.](#)
Journal of Applied Ecology **45**, 1712-1721

Aldridge, D.C., Fayle, T.M. and Jackson, N. (2007)
[Freshwater mussel abundance predicts biodiversity in UK lowland rivers](#)
Aquatic Conservation – Marine and Freshwater Ecosystems **17**, 554-564

Aldridge, D.C., Elliott, P. and Moggridge, G.D. (2006)
Microencapsulated BioBullets for the control of biofouling zebra mussels.
Environmental Science and Technology **40**:975-979

Aldridge, D.C., Elliott, P. and Moggridge, G.D. (2004)
The recent and rapid spread of the zebra mussel, *Dreissena polymorpha*, in Britain.
Biological Conservation **119**: 253-261

Life as a Graduate Student in the Department of Zoology

by

Nick Crumpton and Kelly Richards

The pursuit of a doctorate is a worthy occupation. However, it does the prospective student no good to delude themselves: it's hard work. Obviously, this is true wherever a student researches for their PhD and Cambridge asks as much as it can from its students so don't expect anything different here! What you can expect, though, is one of the most thorough networks of support in any university, spanning the entire department and making sure everyone here does the highest quality, most exciting work they can and earns those 3 very impressive letters.

Your supervisor, obviously, will be your first port of call for academic support but don't forget members of your lab (3rd years and world-weary post-docs are often keepers of the most obscure methods and lab-specific tips... mine their minds!) especially if your supervisor happens to be courted by the press and is partial to flying away unannounced to speak at invitation only, exotic conferences. On top of this support, two 'advisors' are assigned to monitor your progress as you develop through your three years. These will be academics either from within or outside the department whose expertise will compliment those of your supervisor and focus on your field. In order to allow you to plan your time here effectively these advisors will meet with you multiple times during the year and run through your various progress reports such as your Feasibility Report and First Year Report. These milestones are extremely useful in keeping your (often self directed) research going in the right direction and can throw up some unexpected new tangents of interest. For less academic matters the department has an 'Auntie' and 'Uncle'. These are two friendly well-established researchers that can offer support and advice to any worried postgrads.

In addition to all these official lines of support, the staff of the department are, collectively, a powerhouse of academic excellence and always ready to help young researchers beginning their careers. The daily coffee breaks held in the tea room of the main department building are the perfect opportunity to mull over a problem with someone who might be able to offer a fresh insight (or struggled with the same thing themselves). In order to make sure the department remains a dynamic one, term time is chockablock full of visiting speakers, lab meetings, symposia: there's always something around the corner to keep you inspired! Additionally, the regular departmental seminar series are diverse and normally manage to provide something for everyone. They include the Tea Talks, the Beer Talks (specifically for postgraduates), the Evolutionary Development Series and the Behavior, Ecology and Evolution Series. Once you've taken advantage of the research facilities and your project begins to take shape, the Graduate symposium and the departmental seminar day give you the chance to present and discuss your own work alongside that of other researchers, as well as give you an insight to the cutting edge research that goes on outside your own lab.

Postgraduate study is a fantastic opportunity to learn new skills that will further your development as a researcher, this can be anything from learning photoshop to group teaching to German!

The Graduate Development Programme offers a huge range of transferable and specific skills. It's always possible to pick up experience working as part of museum and department outreach groups, working in the library and, of course, teaching undergraduates through demonstrations and supervisions.

Some forms of research can be, by their very nature, solitary affairs but the graduate body is a lively one which interacts as much as possible. Every Friday evening, Happy Hour sees all the scientists dropping their pipettes to relax in the tea room or, weather permitting, in the grass court, with a beer and a jelly snake. The summer BBQs held at Madingley and on the main site are both popular events, whether the sun is being social or not; and as the nights draw in people begin to look forward to the Zoology Christmas Party, which is hosted by a different lab each year and always has a unique flavour, sometimes quite literally! The energetic recruits amongst you can choose to join one of the friendly sports teams, including cricket, football and rounders. Or, if you're more musically minded, the Anima choir takes advantage of the incredible acoustics and slightly surreal setting of the museum gallery to rehearse weekly and host concerts throughout the year. The University also has a Graduate Orchestra which regularly performs in the West Road Concert Hall.

Whether based west of the city at the idyllic rural Madingley site, or under the imposing skeleton of the finback whale sandwiched between the floors of the main building, you'll find the Department of Zoology a stimulating and supportive place in which to research your chosen topic.

Welcome!

Kelly & Nick

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