UNIVERSITY OF CAMBRIDGE
Department of Zoology

NATURAL SCIENCES TRIPOS PART IB

ANIMAL BIOLOGY

COURSE HANDBOOK

2008-2009

Course co-ordinators:
Dr. Robert Asher, tel. (3)36680 [Michaelmas term] e-mail: rja58@cam.ac.uk
Dr Berthold Hedwig, tel (3)36603 [Lent & Easter terms] e-mail: bh202@cam.ac.uk

Contents

Aims and Learning Outcomes of Part IB Animal Biology

Aims

- To show how the form, function and behaviour of animals become adapted to the environment through evolution.
- To elucidate general biological principles through the study of specialised or experimentally tractable systems.
- To prepare students for Part II courses that requires knowledge of animal biology at the systems and organismal levels.
- To develop students' practical scientific skills.

Learning Outcomes

At the end of the course, students should be

- able to appreciate the complexities of biological organisation and be able to address scientifically controversial issues in a rational way.
- able to interpret material in terms of biological function and the effect of natural selection.
- able to analyse and report on material learned.
- able to assess the scope of animal biology and be able to select particular areas for further study.
- aware of the breadth of studies on the biology of animals as they relate to the evolution, function, behaviour and behavioural ecology of animals.
- able to integrate related topics from separate parts of the course.

Suggested general background reading

Bateson, P. & Martin, P. (2000) *Design for a life*. Vintage paperback.

The complete collection of Darwin's publications are available here: http://darwin-online.org.uk/

Dawkins, R. (1990) *The selfish gene*. Oxford University Press, Oxford.

Dawkins, R. (1999) *The extended phenotype.* Revised edition, Oxford University Press, Oxford.

Gould, S. J. (1981) *The Mismeasure of Man.* Norton, New York.

Gould, S.J. (2002) *The Structure of Evolutionary Theory*. Belknap, Harvard. (Note: All of Gould's books of essays are worth reading).

Hughes, H. C. (1999) *Sensory exotica; a world beyond human experience*. MIT Press.

Jones, S. (2000) *Darwin's ghost: the Origin of Species updated.* Random House, London.

Miller, K. (2008) *Only a Theory: Evolution and the Battle for America's Soul.* Viking Press.

Prothero, D. (2007) *Evolution: What the Fossils Say and Why it Matters.* Columbia, New York.

Ridley, M. (1995) *The Red Queen: sex and the evolution of human nature*. Penguin, London.

Ridley, M. (2003) *Nature via nurture: genes, experience and what makes us human.* Harper Collins, London.

Schmidt-Nielsen, K. (1970) *How animals work*. Cambridge University Press, Cambridge.

Course Timetable 2008/2009

***Lectures*: Fri, Mon, Wed 11-12, Main Lecture Theatre, Department of Zoology**
***Practicals*: Wed 12-17 or Thu 12-17, Elementary Laboratory, Department of Zoology**
NOTE - IF IT IS ESSENTIAL FOR YOU TO START THE THURSDAY PRACTICAL BEFORE 12, PLEASE CONTACT NEAL MASKELL (practicals@zoo.cam.ac.uk)

MICHAELMAS TERM

Behaviour and Ecology

Lectures

Prof Nick Davies	**Fri 10 Oct – Wed 22 Oct**
Dr Rebecca Kilner	**Fri 24 Oct – Wed 5 Nov**

Practicals **Wed 15 Oct – Thu 6 Nov**
Prof Nick Davies and Dr Rebecca Kilner

Brains and Behaviour

Lectures

Prof Simon Laughlin	**Fri 7 Nov – Mon 17 Nov and 3 Dec**
Prof Malcolm Burrows	**Wed 19 Nov – Mon 1 Dec**

Practicals **Wed 12 Nov – Thu 4 Dec**
Dr Switbert Ott and Dr Brian McCabe

LENT TERM

Insect Biology

Lectures

Dr Walter Federle	**Fri 16 Jan – Wed 28 Jan**
Dr William Foster	**Fri 30 Jan – Wed 11 Feb**

Practicals **Wed 21 Jan – Thu 12 Feb**
Dr Walter Federle and Dr William Foster

Vertebrate Evolutionary Biology

Lectures

Prof Jenny Clack	**Fri 13 Feb – Wed 25 Feb**
Dr Robert Asher	**Fri 27 Feb – Wed 11 Mar**

Practicals **Wed 18 Feb – Thu 12 Mar**
Prof Jenny Clack and Dr Robert Asher

EASTER TERM*

Evolutionary Principles

Lectures

Dr Rufus Johnstone	***Wed 22 Apr – Mon 4 May**
Dr Nick Mundy	**Wed 6 May – Mon 18 May**

Practicals ***** **Wed 22 Apr – Thu 14 May**
Dr Rufus Johnstone and Dr Nick Mundy

****Note the early start this term***

Supervisions

In Part IB Animal Biology, students are commonly assigned different specialist supervisors for different parts of the course. The appointment of supervisors is the responsibility of your Director of Studies. The course coordinators are (Dr. Rob Asher, e-mail: rja58@cam.ac.uk, tel. (3)36680 for the Michaelmas term; and Berthold Hedwig, e-mail bh202@cam.ac.uk, tel. (3)36603 for the Lent term 2009) can help by informing Directors of Studies of the names of those willing to supervise. When you know the name of your supervisor, get together with your college supervision partners and contact the supervisor in good time. If you do not know the name of your supervisor a few days before the start of the relevant block of lectures, contact your Director of Studies without delay.

You should expect your supervisor to set at least two essays, or comparable exercises, for each half-term section of the course, together with appropriate additional work based on the lectures and practicals. Past Tripos papers are held in the Balfour Library Office and you are well advised to become familiar with the structure of the papers and the sorts of questions that have previously been set. Copies of previous examination papers can be found elsewhere in these notes.

Supervisions offer an extremely valuable opportunity to discuss your work in depth. Not only do they help you to obtain a good understanding of the subject matter; they also help develop your ability to present material orally and in writing.

Course Questionnaires

After each block of six lectures, you are asked by e-mail to complete a questionnaire about that part of the course. It is VERY IMPORTANT that we know your opinions, and in the past we have been able to act on some excellent ideas that students have contributed. So PLEASE COMPLETE THE QUESTIONNAIRES.

Student Representatives

Four student representatives, two from the Wednesday practical class and two from the Thursday practical class, are elected by students early in the Michaelmas Term and constitute one of the ways in which feedback about the lectures, practicals and supervisions is obtained. The student representatives meet the course management committee at the end of each term to review the progress of the course. The student representatives also devise a questionnaire that is given, in the Easter term, to all students taking IB Animal Biology, and present the information in the returns to the management committee after the Tripos examinations. In the past, this end-of-year questionnaire has been invaluable in planning for the following year. You may, of course, direct comments directly to the course coordinator or to other members of staff whenever you wish.

Practical Classes

Associated with each block of 12 lectures are two practical classes, the first practical running for the first two weeks of the lecture block and the second practical running for the remainder. Each practical write-up will be assessed and returned to you. The assessment will count towards your mark in the Tripos examination. At registration for the practical classes at the beginning of the Michaelmas term, you will be asked to sign up for either the Wednesday or the Thursday practicals. You will also be allocated, either to the group doing practicals in the odd-numbered weeks, or to the group doing practicals in the even-numbered weeks. Please ensure you sign the register for each practical class you attend. The register, along with other information, will be posted on the Animal Biology noticeboard in the Elementary Lab. If for some reason you cannot attend your assigned practical time please email practicals@zoo.cam.ac.uk with details.

Safety in the Practical Class

- If you suffer from an allergy or other medical condition that you think might place you at risk during practicals, inform the teaching officer in charge of your practical class.
- Follow safety instructions carefully and wear protective clothing when required.
- Keep water away from mains-powered equipment.
- Do not eat, drink or smoke in the laboratory.
- When in the practical class, cover all wounds, even minor cuts and abrasions.
- If an accident occurs, no matter how minor, inform a demonstrator or technician immediately.
- Ensure that you know where the fire exits are located. The fire signal is a continuous sound from a klaxon or bell. On hearing this sound, leave the classroom immediately under the guidance of the person in charge of the class.
- Always be alert for what might go wrong – intelligence and vigilance have averted many a disaster.

CamTools

You will be registered to use the IB Animal Biology web site (https://camtools.cam.ac.uk), where material and information, as determined by the individual lecturer, about the course may be accessed. Suggestions to Rob Asher (rja58@cam.ac.uk, Michaelmas 2008), Berthold Hedwig (bh202@cam.ac.uk, Lent 2009) or Rachel Aucott (ra338@cam.ac.uk) for effective use of this facility would greatly be appreciated.

Synopses of Lectures and Practicals

Behaviour and Ecology

Aims and Overview

We seek to share with you the scientific study of animal behaviour, showing how predictions can be derived from evolutionary theory and tested by comparative studies and experiments. In addition, we encourage you to think critically about how well observations match theoretical predictions and to consider alternative hypotheses, and to discuss from an evolutionary point of view how survival and reproductive strategies relate to the ecological and social environment. We consider in detail adaptive modifications of behaviour, how the evolution of a behaviour is influenced by its development, and how an understanding of behaviour can contribute to animal welfare.

The first two lectures give an evolutionary perspective of how animals' survival and reproductive strategies relate to their physical environment and an environment consisting of competitors and predators. Then follow four lectures considering in detail the various problems individuals have concerning survival and reproduction: foraging, avoidance of predators and brood parasites, parental care and co-operation and conflict in societies. The next four lectures look at the mechanisms that underpin adaptive behaviour, and the way in which it develops, by examining trade-offs, navigation and recognition cues. The final two lectures show how understanding the mechanisms underpinning adaptive behaviour can help us understand the process of speciation and can also help improve the welfare of captive animals. Throughout the course the emphasis is on the links between ecology, behaviour and evolution. Ecological factors provide the stage on which behaviour is played and, during evolution, natural selection will favour those behavioural strategies which maximise an individual's chances of survival and its reproductive efficiency.

The practicals involve experiments to test some of the hypotheses discussed in the lectures so students will gain first-hand experience of collecting and analysing quantitative data on behaviour, of testing alternative predictions, and of writing concise reports to summarise conclusions.

Lectures 1 - 6
Prof. Nick Davies

(e-mail nbd1000@cam.ac.uk, tel 34405)

References

Alcock, J. (2005) *Animal Behaviour*. 8th Edition. Sinauer.
Krebs, J.R. & Davies, N.B. (1993). *An Introduction to Behavioural Ecology*. 3rd edition. Blackwell Scientific Publications.

1. Evolution of reproductive rates (Fri 10 Oct)

Asking questions about reproduction, illustrating the distinction between proximate and ultimate explanations for behaviour. Selfish individuals or group advantage? Field experiments on optimal clutch size in birds. Variations in clutch size within a species. Why do some species apparently not lay the optimal clutch size? Optimal clutch size in other animals. Lion cooperation.

Alcock, J. (2005) *Animal Behaviour* 8th Edition, Chapter 1.
Borgerhoff Mulder, M. (1998). The demographic transition : are we any closer to an evolutionary explanation? *TREE* 13, 266-70.

2. Ecology and life histories (Mon 13 Oct)

Optimal life history strategies – trading off adult survival and reproductive effort. Semelparity versus iteroparity. Ecology and life histories. Ovulation signals in primates as an example of the comparative method.
Ghalambor, C.K. & Martin, T.E. (2001). Fecundity - survival trade-offs and parental risk taking in birds. *Science* 292, 494-7.

3. Provisioning young (Wed 15 Oct)

Collecting food for the young – the central place foraging model. When observations do not fit a model's predictions, what should we do? Brood hierarchies. Parent-offspring conflict – models of genetic conflicts of interest. How should this genetic conflict affect brood reduction? Parental control of food allocation and brood reduction.

Kilner, R. & Johnstone, R. A. (1997) Begging the question: are offspring solicitation behaviours signals of need? *Trends in Ecology and Evolution* 12, 11-15.
Haig, D. (1993). Genetic conflicts in human pregnancy. *Q. Rev. Biol*. 68, 495-532.

4. Parents that cheat: the brood parasites (Fri 17 Oct)

Cheats and honest workers. The common cuckoo. Cuckoo host races. Cuckoo-host coevolution. Mechanisms of host rejection of the parasite egg. Cuckoos vs. hosts – who wins? Evolution in action? Why do hosts of common cuckoos never reject cuckoo chicks? Vocal trickery by cuckoo chicks.

Winfree, R. (1999) Cuckoos, cowbirds and the persistence of brood parasitism. *Trends in Ecology and Evolution* 14, 338-343.
Kilner, R.M., Madden, J.R. & Hauber, M.E. (2004) Brood parasitic cowbird nestlings use host young to procure parental resources. *Science* 305, 877-9.

5. Competing for resources (Mon 20 Oct)

G.A. Parker's study of dungflies. The best way to behave often depends on what your competitors are doing. The evolution of conventional fighting. Some examples of contests in nature. Honest signalling.

Krebs, J.R. & Davies, N.B. (1993). *An Introduction to Behavioural Ecology*. 3rd edition. (Chapter 7).

6. Group living: foraging efficiency and predation (Wed 22 Oct)

Group living can reduce predation. Group living can improve feeding efficiency. There are also costs of living in a group – foraging-predation trade-offs. In theory there may be an optimal group size, but it may not be stable. Lions and wild dogs test the theory.

Clutton-Brock, T.H. et al. (1999). Selfish sentinels in cooperative mammals. *Science* 284, 1640-4.

Lectures 7-12
Dr Rebecca Kilner

(e-mail rmk1002@cam.ac.uk, tel. 31766)

References

Alcock, J. (2005) *Animal Behavior: an Evolutionary Approach*. 8th Edition. Sinauer Associates.
MacFarland, D. (1999) *Animal Behaviour*, Longman, 3rd Edition.
Krebs, J.R. & Davies, N.B. (eds) *Behavioural Ecology: An Evolutionary Approach* 4th Edition (meerkats on the cover)
Schilthuizen, M. (2000) *Frogs, flies and dandelions: the making of species*. Oxford University Press.

7. The development of behaviour (Fri 24 Oct)

In this lecture we focus on how adaptive behaviour develops. In the first part of the lecture we examine the sources of variation in behaviour, by looking at genotypic and environmental influences on behavioural development. In the second part of the lecture, we see how natural selection can maintain variation in behaviour.

Chapters 2 and 3 in Alcock, J. (2005) *Animal Behavior: an Evolutionary Approach*. 8th Edition. Sinauer Associates.

8. Trade-offs (Mon 27 Oct)

Here we focus on one sort of genetic interaction with the environment by looking the mechanisms that underlie the many sorts of trade-offs that animals must make. Trade-offs occur in diverse contexts and can influence levels of protein expression, morphological development and life history cycles. Nevertheless, the mechanisms underlying these trade-offs have several features in common.

Ketterson, E.D. & Nolan, V. (1992) Hormones and life histories: an integrative approach. *American Naturalist* 140:S33-S62.
Emlen, D.J. (2001) Costs and diversification of exaggerated animal structures *Science* 291:1534-1536

9. Navigation (Wed 29 Oct)

This lecture considers the mechanisms that animals use for finding their way. Studies of navigation provide insights into the ways that animals use sensory information from cues in the physical environment to determine their behaviour. We look at the mechanisms determining how migratory animals find their way to and from their breeding grounds and how foraging bees find their way to and from the hive.

MacFarland, D. (1999) *Animal Behaviour*, Longman, 3rd Edition. pp 250-258
Esch, H.E., Zhang, S., Srinivisan, M.V. & Tautz, J. (2001) Honeybee dances communicate distances measured by optic flow *Nature* 411:581-583

10. Recognition (Fri 31 Oct)

This time we consider how the social environment influences the mechanisms underlying behavioural development by focusing on the problem of recognition. Recognition plays a key role in social evolution, sexual selection and speciation. Here we look at the general rules used for self-recognition, recognizing kin and recognizing mates throughout the animal kingdom. We consider whether signatures for recognition should be determined genetically or environmentally and how animals might best perceive and respond to cues for recognition.

Sherman, P.W., Reeve, H.K. & Pfennig, D.W. (1997) Recognition systems. Chapter 4 in Krebs JR & Davies NB *Behavioural Ecology: An Evolutionary Approach* 4th Edition (meerkats on the cover)
Hauber, M.E. & Sherman, P.W. (2001) Self-referent phenotype matching: theoretical considerations and empirical evidence *Trends in Neurosciences* 24:609-615

11. Speciation (Mon 3 Nov)

We will look at how the mechanisms underlying the way in which behaviour develops can contribute to the process of speciation. We see how trade-offs, navigational mechanisms and recognition systems can each promote reproductive isolation, the starting point for speciation.

Chapters 1 and 4 in Schilthuizen, M. (2000) Frogs, flies and dandelions: the making of species. Oxford University Press.

12. Evolution and animal welfare (Wed 5 Nov)

The welfare of animals kept in captivity affects all of us, every day. We depend on captive animals for clothes, shoes and food, and farming practices have wide-ranging implications for human health. Animal testing is a key element of medical and fundamental biological research. Zoos, and their captive breeding programmes, are the last refuge for many species that are on the brink of extinction in nature. In this lecture we see how understanding the evolution of behaviour can improve animal welfare and increase the chance that captive breeding programmes are successful at preventing extinction.

Dawkins, M.S. (1998) Evolution and animal welfare. *Quarterly Review of Biology* 73, 305-328.

Mason, G.J., Cooper, J. & Clarebrough, C. (2001) Frustrations of fur-farmed mink. *Nature* 410, 35-36.

Practicals
Prof. Nick Davies & Dr Rebecca Kilner

1. The costs and benefits of grouping by prey

We will test two ideas about how grouping may reduce predation: the dilution effect and the confusion effect.
Film: Stickleback behaviour.
(Wed 15/Thu 16 Oct and repeated the next week, Wed 22/Thu 23 Oct).

2. Vigilance and group size in barnacle geese

Measurements will be made from a video film in order to investigate factors that may influence vigilance.
Film: The private life of the cuckoo.
(Wed 29 /Thu 30 Oct, repeated Wed 5 Nov/Thu 6 Nov)

Brains and Behaviour

Aims and Overview

We aim to develop an understanding of common principles of neural function that are shared by a wide range of animals. The lectures illustrate how nervous systems have solved the operational problems posed by the need to generate patterns of behaviour. Our examples demonstrate the elaboration of neural circuits in sensory and motor systems that has permitted the exploitation of different habitats and the development of different lifestyles. The lectures illustrate the progression from simple systems to the more complex, and the changes in molecular and cellular structure that underlie changes in function. By linking the working of the nervous system to patterns of behaviour you will gain a basic understanding of the levels of internal organisation required to generate an adaptive response to the environment. This understanding will enable you to appreciate the many specialisations that have permitted the evolution of animal behaviour.

Lectures 1 - 6
Prof. Simon Laughlin

(e-mail s.laughlin@zoo.cam.ac.uk, tel 36608)

1. An introduction to nervous systems and neuronal function (Fri 7 Nov)

The aim is to introduce the structure of nervous systems and the mechanisms responsible for the generation of neural signals at the elementary level required for this module. Brains are networks of neurons that have elaborated during the course of evolution to generate ever more complicated patterns of behaviour. The basic electrical and chemical signalling mechanisms of neurons and their synapses will be reviewed and their advantages and disadvantages discussed. The treatment is very simple and follows on from the Biology of Cells in Part IA. The detailed factual description of neurophysiology given in classical physiology courses is not required.

Simmons, P. J. & Young, D. (1999) *Nerve Cells and Animal Behaviour* 2nd Edition. Cambridge University Press. GP193b chapters 1 & 2 (basic account).
Delcomyn, F. (1998) *Foundations of Neurobiology*, Freeman, Chapters 1-8. GF 9.

2. Information processing in simple circuits (Mon 10 Nov)

The aim is to show how the molecular and cellular building blocks of the nervous system are arranged in circuits that determine behaviour, and to introduce you to the difficulties that confront experimentalists who set out to discover what neurons do. Examples include the coding and processing of sensory information in *Limulus* lateral eye, a motion detecting neuron in the blowfly, and a synaptic mechanism for learning in the gastropod mollusc, *Aplysia*.

Delcomyn, F. (1998) *Foundations of Neurobiology*, Freeman, Chapt. 9. GF 9.
Carew, T.J. (2000) *Behavioural Neurobiology*, Sinauer. Chapt. 10.

3 & 4. Auditory localisation by the barn owl (Wed 12 Nov and Fri 14 Nov)

The aim is to show how the processing of sound by its auditory system enables an owl to identify the position of prey with the precision required to hunt in total darkness. We see how the quantitative analysis of behaviour, and an elementary knowledge of sound, defines the cues that the owl uses to locate objects. This knowledge of the underlying computation guides a physiological analysis of the auditory pathways that has demonstrated a number of important general principles, including parallel processing, the computation of delays and the construction and function of maps in the brain.

Delcomyn F. *Foundations of Neurobiology*, Freeman, (1998) Chapters 12. GF 9.
Konishi, M. (1993) Listening with two ears. *Scientific American* 268**,** 34-41.
Simmons & Young, (*ibid*) Chapter 6.

5. Echolocation by bats (Fri 14 and Mon 17 Nov)
The aim to show that bats' calls and the auditory processing of echoes are exquisitely well adapted for hunting by echolocation. Once again, our understanding is guided by a knowledge of behaviour and the fundamental environmental constraints within which behaviour operates. These basic factors define the task executed by the brain. Calls are structured and controlled to suit habitat, prey and behavioural context. Sensory mechanisms are adapted to improve echolocation by maximising sensitivity and acuity and minimising interference from other bats. The mapping of information in the auditory cortex plays a crucial role in extracting information on the position, range and velocity of approaching prey.

Delcomyn F. *Foundations of Neurobiology*, Freeman (1998) Chapters 12. GF 9.
Suga, N. (1990) Biosonar and neural computation in bats. *Scientific American* 262**,** 34-41.

6. The design and evolution of nervous systems (Wed 3 Dec)

The aim is to show how nervous systems have responded to selective pressure. We will consider the factors that are likely to have shaped nervous systems during evolution; namely the benefits and the costs of elaborating neurons and nervous systems. We will then discuss the evidence that nervous systems are adapted to operate efficiently, by improving cost:benefit ratios within biological constraints. We will close by asking, what does it mean to have a bigger brain?

Allman, J. (2000) Evolving Brains. *Scientific American Library*.
Streidter, G.F. (2005) *Principles of Brain Evolution* (*esp.* Chapts 1 & 9). Sinauer.

Lectures 7 - 12
Prof. Malcolm Burrows

(e-mail m.burrows@zoo.cam.ac.uk, tel 36601)

Reference

Carew, T. J. (2000) *Behavioural neurobiology*. Sinauer, Sunderland Mass. USA.

7. Olfaction (Wed 19 Nov)

This lecture describes how insects respond to an odour and analyses how they discriminate particular odours from all the others. Most insects release pheromone odours to attract a mate and these elicit a specific behaviour which can then be used to help our understanding of the way odour signals are processed in the brain. The lecture will describe the behaviour of male moths and cockroaches to a pheromone released by females, and will ask how the odour is detected, analysed in the brain, and then integrated with other stimuli to produce an appropriate behavioural response.

Topics covered

1. Behaviour of insects in the presence of a pheromone.
2. Design of antennae for the detection of scarce molecules.
3. Structure and function of olfactory receptors.
4. How are the odour molecules transduced into electrical signals?
5. How do the neurones in the brain process the odour signals?
6. Are there specialisation in the brain for the detection of pheromones?
7. Are there any general principles for the processing of odours?
8. Are there similarities to the ways that vertebrates process odour signals?

Shepherd, G.M. (1994) Chemical Senses. In *Neurobiology* 3rd Edition. Oxford University Press.

Ferrus, A. and Canal, I. (1994) The behaving brain of a fly. *Trends in Neurosciences* 17, 479-490.

Laurent, G. (1996) Dynamical representation of odors by oscillating and evolving neural assemblies. *Trends in Neurosciences* 19, 489-496.

Leinders-Zufall, T. et al. (2000) Ulrasensitive pheromone detection by mammalian vomeronasal neurons. *Nature* 405, 792-796.

Web Sites

Insect pheromones
http://www.pheromone.ekol.lu.se/
http://soma.npa.uiuc.edu/courses/neuroethol/models/pheromone_searching/pheromone_searching.html
Vertebrate olfaction
http://www.leffingwell.com/olfaction.htm

8. Vision in Flies (Fri 21 Nov)

This lecture examines how insects with eyes of quite different design to those of vertebrates solve particular visual tasks. The chasing behaviour of flies will be analysed to illustrate the types of visual problems that must be solved while flying. The processing of visual stimuli through the various stages in the brain and the

contribution of individual interneurones will be described. The role of other sense organs in stabilising and controlling flight will also be analysed.

Topics covered
1. The chasing behaviour of houseflies
2. Structure and function of compound eyes
3. Organisation of the visual pathways in the brain
4. Early processing of the visual signals
5. Where is information about movement extracted?
6. Neurones specific to males
7. Ocelli (simple eyes) as horizon detectors
8. Halteres and the stabilisation of flight
9. Convergence of sensory signals onto motor neurones

Simmons, P.J. and Young, D. (1999) Nerve cells and animal behaviour. Cambridge University Press. Chapter 5.
Weckström, M and Laughlin, S.B. (1996) Visual ecology and voltage-gated ion channels in insect photoreceptors. *Trends in Neurosciences* 18, 17-21.
Hardie, R.C. (1986). The photoreceptor array of the Dipteran retina. *Trends in Neurosciences* 9, 419-423.

Web Sites
Flybrain
http://flybrain.uni-freiburg.de/
How the world may look through a bee's eye
http://cvs.anu.edu.au/andy/beye/beyehome.html
Polarised light sensitivity
http://www.polarization.com/eyes/eyes.html
Webcam on ant colony
http://antcam.nhm.ac.uk:80/index.html

9. Electric Sense (Mon 24 Nov)

This lecture examines the unusual sensory capabilities of some animals (mostly fish) to detect and respond to electrical stimuli in the environment, or those that they or other animals generate. To use this sense some fish have evolved special receptors - electroreceptors - and some have evolved organs to generate specific electrical signals. Fish and other animals with an electric sense may use it in navigation, or to detect the electric fields generated by their prey. The presence of an electric organ also allows the electric sense to be used as a private means of communication between members of the same species, and in electrolocating objects in the environment. Electric fish can be sub-divided into two groups: those that produce a strong electric discharge and those that produce a weak discharge. The fish with a weak discharge can then be further sub-divided on the form of their electric discharge into **pulse** or **wave** species.

Topics covered
1. Prey detection and navigation
2. Electric organs and electric organ discharges
3. Pulse and wave forms of electric discharge
4. Electroreceptors; their structure and function

5. How the electric image is represented in the brain
6. Electrolocation
7. Social communication

Kalmijn, A.J. (1982) Electric and magnetic field detection in elasmobranch fishes. *Science* 218, 916-918.
Scheich, H. et al (1986) Electroreception and electrolocation in platypus. *Nature* 319, 401-402.
Kramer, B. (1996) Electroreception and communication in fishes. Gustav Fischer, Stuttgart.
Moller, P. (1995) Electric fishes: history and behaviour. *Chapman and Hall*, London.
Turner, R.W. et al. (1999) Electroreception and electrocommunication. *J. Exp. Biol.*, 202.

Web Sites
Jamming avoidance response
http://soma.npa.uiuc.edu/courses/neuroethol/models/jamming_avoidance/JAR.html
Electric fish :
http://www.globalserve.net/~nberman/primer.html
Films of electric fish:
http://www.bbb.caltech.edu/ElectricFish/qtmov.html

10. Control of Movement (Wed 26 Nov)

This lecture explores some of the neural mechanisms that generate and control simple movements. It describes selected movements in particular invertebrates that illustrate some of the basic mechanisms. It begins with simple movements that are a response to a single stimulus and which require no sensory feedback. It continues with movements for which sensory control is necessary and describes the mechanisms by which this sensory feedback can influence a movement. Finally, the properties and connections of neurones in the central nervous system that produce the basics of a rhythmical motor pattern - a *central pattern generator* - will be described.
Topics covered
1. What sorts of movements can be analysed?
2. Strike of mantis shrimps
3. Eye movements of crabs
4. Escape movements in crayfish
5. Why sensory feedback is needed?
6. Centrally generated patterns of movement
7. Cellular mechanisms for the production of motor patterns

Shepherd, G.M. (1994). Locomotion. In *Neurobiology* 3rd Edition. Oxford University Press.
Burrows, M. (1969). The mechanics and neural control of the prey capture strike of the mantis shrimps Squilla and Hemisquilla. *Z. vergl. Physiol*., 62, 361-381.
Morton, D.W. and Chiel, H.J. (1994) Neural achitectures for adaptive behaviour. *Trends in Neurosciences* 17, 413-420.

Selverston, A.I. (1977). Mechanisms for the production of rhythmic behavior in Crustaceans. In *Identified Neurons and Behavior of Arthropods*. ed. Hoyle, G. Plenum Press, N.Y. pp 209-225.

Web Sites
Mantis shrimps:
http://www.blueboard.com/mantis/
Stomatogastric ganglion:
http://www.pbrc.hawaii.edu/STG/STGoverview.html
Respiratory pattern generators:
http://www.voicenet.com/~rybak/resp.html

11. Flying and Singing in Insects (Fri 28 Nov)

This lecture describes the way that flight is generated in insects, particularly the locust. The neurones responsible can be identified and their anatomical and physiological properties revealed. The basis of the rhythmical movements of the wings is produced by a central pattern generator, but the motor output produced is strongly influenced by sensory information from the moving wings. Finally, the way this basic machinery is used by other insects to produce song will be described.

Topics covered
1. Two basic mechanisms for producing flight
2. The flight pattern in insects with synchonous muscle
3. How the pattern is produced
4. Role for sensory feedback
5. The flight pattern is modified to produce singing in crickets
6. Types of song produced by a cricket
7. Genetic dissection of the song mechanism

Simmons, P.J. and Young, D. (1999) Nerve cells and animal behaviour. Cambridge University Press. Chapter 7.
Robertson, R.M. (1986) Neuronal circuits controlling flight in the locust: central generation of the rhythm. *Trends in Neurosciences* 9, 278-280
Burrows, M. (1996) Neurobiology of an insect brain. Oxford University Press. Chapter 11.

Web Sites
Locust plagues:
http://www.fao.org/NEWS/global/LOCUSTS/Plagues.htm
Locust information:
http://www.fao.org/NEWS/GLOBAL/locusts/LocFAQ.htm
Cricket song:
http://www.ac-toulouse.fr/svt/gdescrip.html

12. Walking (Mon 1 Dec)

This lecture examines the mechanisms that generate and control walking in animals, particularly in mammals, but with reference to similar mechanisms in insects. It starts by considerating the types of gaits that are used and the methods used to analyse and describe the limb movements. It then analyses the brain and spinal mechanisms that generate the basic locomotory rhythms. Then it describes the types of sensory influences that modify the walking pattern and enable stable posture and locomotion to be achieved. Finally, models are described that seek to give a greater insight into the underlying neural mechanisms.

Topics covered

1. Types of gaits used by animals
2. The step cycle and the action of the leg muscles
3. Identification of regions in the brain that control locomotion
4. Organisation of patterns by the spinal cord
5. Influence of sensory feedback on locomotion
6. Reflexes that control the step cycle
7. Do these principles apply to other animals?

Shepherd, G.M. (1994). Locomotion. In *Neurobiology* 3rd Edition. Oxford University Press.
Pearson, K.G. (1976) The control of walking. *Scientific American* 235, 72-86.
Muybridge, E. (1957 reprint of 1887 book). Animals in Motion. Dover Publications.
Muir, G.D. & Steeves, J.D. (1997) Sensorimotor stimulation to improve locomotor recovery after spinal injury. *Trends in Neurosciences* 20, 72-77.

Web Sites

Muybridge and animal gaits
http://www.king.ac.uk/muytext1.htm
http://www.sfmuseum.org/hist3/sallie.html

Practicals
Dr Switbert Ott and Dr Brian McCabe

1. Locust motor system

The motor activity of a Locust hindleg muscle will be analysed during jumping behaviour.
(Wed 12/Thu 13 Nov, repeated on Wed 19/Thu 20 Nov).

2. The discharges of an electric fish

The electrolocation system of a weakly electric fish is investigated.
(Wed 26/Thu 27 Nov, repeated on Wed 3/Thu 4 Dec)

Insect Biology

Aims and Overview

We seek to convey to you an understanding of the biology of the insects, in particular their physiology, feeding biology, mating and reproductive behaviour, and the evolution of social behaviour. We will show how the study of insects contributes to our understanding of broad principles of evolutionary biology, and provide students with direct experience of handling, observing and studying living insects.

Insects are the most abundant and successful group of land animals. The course will outline the secret of the insects' success by a detailed study of their design and the adaptations of this design to an enormous diversity of lifestyles.

The lectures will cover the insect cuticle, respiration, water balance and locomation; insect parasitoids; mating strategies; and the evolution of insect societies.

Lectures 1 – 6
Dr Walter Federle

(e-mail wf222@cam.ac.uk, tel 63435)

References

Chapman, R.F. (1998) *The Insects: structure and function*. Cambridge University Press 4th Edition.

Gullan, P.J. & Cranston, P.S. (2005) The insects: an outline of entomology. Oxford: Blackwell Publishing, 3rd Edition.

1. Cuticle (Fri 16 Jan)

Cuticle is an extremely adjustable and multifunctional material, essential for virtually every aspect of insect biology. The diverse functions of cuticle, inner structure and composition, material properties (sclerotization and plasticization, resilin), moulting, cuticle colours.

Hadley, N. (1986) The arthropod cuticle. *Scientific American* 255, 104-112.

Miller, T.A. (1980) Cuticle techniques in arthropods. In *Springer Series in experimental entomology*, (ed. T.A. Miller), Springer, New York.

Vincent, J.F.V. & Wegst, U.G.K. (2004) Design and mechanical properties of insect cuticle. *Arthropod Struct. Devel.* 33, 187-199.

2. Respiration (Mon 19 Jan)

How do flying insects achieve some of the highest known mass-specific rates of 0_2 consumption in the animal kingdom? Structure of the tracheal system, respiration and body size, mechanisms of respiration control, discontinuous gas exchange, respiration in aquatic insects.

Withers, P.C. (1992) Comparative animal physiology: Saunders College Publishing. Chapter 13.
Quinlan, M.C. & Gibbs, A.G. (2006) Discontinuous gas exchange in insects. *Respiratory Physiology & Neurobiology* 154, 18-29.
Hetz, S.K. & Bradley, T.J. (2005) Insects breathe discontinuously to avoid oxygen toxicity. *Nature* 433, 516-519.

3. Water balance (Wed 21 Jan)

Water balance and osmoregulation are essential for the ecological success of insects. How do insects prevent water loss, regulate osmotic balance and absorb water from the air?

Maddrell, S.H.P. (1981) The functional design of the insect excretory system. *Journal of Experimental Biology* 90, 1-15.
Parker, A.R. & Lawrence, C.R. (2001) Water capture by a desert beetle. *Nature* 414, 33-34.
Schmidt-Nielsen, K. (1990) Animal Physiology: Adaptation and Environment. Cambridge: Cambridge University Press. 4th Edition.

4. Insect feeding (Fri 23 Jan)

What adaptations have insects evolved for acquiring and processing food? Insect mouthparts and alimentary canal, nutritional constraints involved in the consumption of different diets, carnivory, blood feeding, xylem/phloem feeding, symbioses with microorganisms.

Chown, S.L. & Nicolson, S.W. (2004) Insect physiological ecology: mechanisms and patterns. Oxford: Oxford University Press.

5. Locomotion (Mon 26 Jan)

How do insects walk, run, jump and fly? What are the mechanical constraints for each mode of locomotion and what adaptations have insects evolved?

Vogel, S. (2003) Comparative biomechanics: life's physical world. Princeton/Oxford: Princeton University Press.

6. Insects and Plants (Wed 28 Jan)

Interactions between plants and insects play a key role in most land ecosystems. Insect pollination, plant defences, adaptations of insects to overcome plant defences, ant-plant mutualisms and coevolution.

Gullan, P.J. & Cranston, P.S. (2005) The insects: an outline of entomology. Oxford: Blackwell Publishing, Chapter 11.

Lectures 7 – 12
Dr William Foster
(e-mail waf1@cam.ac.uk, tel 36615)

References

Chapman, R.F. (1998) *The insects: structure and function*. 4th Edition, Cambridge University Press.

Gullan, P.J. & Cranston, P. S. (2005) *The insects: an outline of entomology,* 3rd Edition, Cambridge University Press, Cambridge.

O'Toole, C. (editor) (1995) *The encyclopedia of insects*. Andromeda, Oxford. Well illustrated and authoritative.

McGavin, G.C. (2001) *Essential entomology.* Oxford University Press.

Speight, M.R., Hunter, M.D. & Watt, A.D. (2008). Ecology of Insects, 2nd Edition, Wiley-Blackwell

7. Parasitoids (Friday 30 Jan)

What is a parasitoid? Natural history and classification. Parasitoids in biological control. Host location. Host discrimination. Host defences and parasitoid coutermeasures.

Godfray, H.C.J. (1994) *Insect parasitoids: behavioural and evolutionary ecology*. Especially chapters 1 and 6.

Gauld, I. & Bolton, B. (1988) *The Hymenoptera*, pp 11-29.

8. Sex and reproduction (Mon 2 Feb)

Reproduction. Basic system; variations on a theme. Asexual reproduction. The sex ratio.

Krebs, J.R. and Davies, N.B. (1993) *An introduction to behavioural ecology*, 3rd Edition, chapter 8, pp 175-182.

Trivers, R.L. (1985) *Social evolution.* Chapter 11, pp 271-285.

Godfray, H.C.J. (1994) *Parasitoids: behavioural and evolutionary ecology*. Princeton University Press. Chapter 5, pp 212-224.

9. Mating behaviour and sexual selection (Wed 4 Feb)

Sexual selection theory. Getting the sexes together. Intrasexual selection. Intersexual selection.

Krebs, J.R. & Davies, N.B. (1993) *An introduction to behavioural ecology*, 3rd Edition, chapter 8, pp 183-207.

Choe, J.C. & Crespi, B.J. (1997) *The evolution of mating systems in insects and arachnids*, Cambridge University Press.

Simmons, L.W. (2001) Sperm competition. Chapters 1 and 7. Princeton University Press.

10. Social insects 1 (Fri 6 Feb)

What is a social insect? The natural history of a primitive and of an advanced social insect. The importance of caste. Physical and temporal castes.

Wilson, E.O. (1971) *The insect societies*.
Wilson, E.O. (1975) *Sociobiology*. Chapter 20, pp397-437, The social insects.
Gullan, P.J. & Cranston, P.S. (2005) *The insects*. Chapter 12.

11. Social insects 2 (Mon 9 Feb)

The problem. Two routes to eusociality. Hamilton's rule. Ecological conditions favouring the evolution of social behaviour. Genetic predispositions. Maintenance of eusociality.

Krebs, J.R. and Davies, N.B. (1993) *An introduction to behavioural ecology*, 3rd Edition, chapter 13. Altruism in social insects. pp 318-348.

12. Biodiversity and Conservation (Wed 11 Feb)

How many species of insects are there? What is their past and current distribution? What processes determine insect diversity? How important is insect biodiversity and how might we conserve it?

Speight et al. (2008) *Ecology of Insects*. Chapters 9 and 10.
Samways, M.J. (2005) *Insect Biodiversity Conservation*. CUP

Practicals
Dr Walter Federle and Dr William Foster

1. Aquatic respiration
Experiments will be carried out on the respiration of aquatic insects.
(Wed 21/Thu 22 Jan or Wed 28 Jan/Thu 29 Jan).

2. Anatomy of the desert locust
Students will dissect and draw the alimentary system of a locust.
(Wed 4/Thu 5 Feb or Wed 11/Thu 12 Feb).

Vertebrate Evolutionary Biology

Aims and Overview

The lectures aim to introduce the vertebrates and their diversity and to outline their fundamental structures, common inheritance and unique specialisations. Through a synthesis of evolutionary and developmental studies, combining information from living and fossil species, the course aims to provide a good working knowledge of vertebrate anatomy and evolution. Practical classes complement the lecture material and also aim to teach skills of observation and interpretation using laboratory specimens and the collections of the Museum of Zoology.

In this section of Animal Biology, we ask questions such as what are the vertebrates? How are they put together? How do they fit into the Tree of Life? In addressing these questions, we discover more about ourselves and learn about the patterns and processes of evolution which underlie the whole of biology.

The first lecture will introduce the different groups of vertebrates, familiar and unfamiliar, and briefly outline their relationships. The second lecture will cover vertebrate embryology, and introduce some basic concepts of vertebrate structure. Some examples of 'primitive' vertebrates will be introduced in more detail. The third lecture will deal with vertebrate hard tissues, their structure, origin and distribution in the body and throughout the vertebrate family tree, and the structure of the skull will be introduced. In the fourth lecture, the structure of the postcranial skeleton - limbs, fins, vertebrae, will be studied, while the fifth looks at blood circulation and breathing. A lecture on sensory systems completes the course and recaps the previous material.

In lectures 7-12, the biology of amniotes is considered to illustrate how a common set of embryological features unifies an otherwise very diverse array of vertebrates. Topics include amniote diversity, the evolution of viviparity, circulatory and respiratory systems, metabolism, feeding mechanisms, and hearing. Examples are drawn from both living and fossil amniote clades.

Lectures 1 – 6
Prof. Jenny Clack

(e-mail j.a.clack@zoo.cam.ac.uk; tel 36613)

References

Kardong, K.V. (1998 or 2001) *Vertebrates. Comparative Anatomy, Function, Evolution,* Second or third edition, McGraw-Hill. The first six lectures will be strongly based on this volume, and you will get clear guidance as to which parts are relevant for each lecture. Insist that your college buys a copy. One of the most comprehensive text books I have found, with most of what we cover. It also has some useful historical background information. These editions are updated from the earlier one, and this is particularly important in that he has introduced cladistic classification for the most part.

Liem, K.F., Bemis, W.E., Walker, W.F. & Grande, L. (2001) *Functional Anatomy of the Vertebrates*, 3rd Edition, Harcourt College Publishers. See also http:///www.bio.umass.edu/biology/bemis/FAOV.PPTS/FAOV3.htm for downloadable figures.

Shubin, N. (2008) *Your Inner Fish* Pantheon Books, New York. A non-technical account of vertebrate structure and evolution and the relation of vertebrates to other organisms. Told in a lively way, it brings the evolutionary story to life. Aside from a few inaccuracies (can you spot them?) and omissions (how can you write a book on vertebrate evolution without mentioning neural crest?), strongly recommended.

WWW pages relevant to vertebrate evolutionary biology can be found at The Tree of Life, University of Arizona, http://phylogeny.arizona.edu/tree/eukaryotes/animals/chordata.html. This an hierarchically arranged system of pages aiming ultimately to describe all living forms in their phylogenetic context, with a summary of information about each one. It is far from complete.

1. The Vertebrate Family Tree (Fri 13 Feb)

This lecture will introduce the different groups of vertebrates, familiar and unfamiliar, and briefly outline their relationships. It will cover some aspects of their phylogeny and look at which characters unite different groups to one another. Most of these characters will be dealt with in more in other lectures.

2. Eggs, Notochords and chordates (Mon 16 Feb)

Here, we will cover vertebrate embryology, and introduce some basic concepts of vertebrate structure. Some examples of 'primitive' vertebrates will be introduced in more detail, to illustrate the basic structure of a vertebrate head.

3. Vertebrate Hard Tissues (Wed 18 Feb)

This lecture will deal with vertebrate hard tissues, their structure, origin and distribution in the body and throughout the vertebrate family tree. The structure of the skull and vertebral column will be introduced, with an illustration of some of the ways the skull has evolved in different vertebrates.

4. From Fins to Limbs (Fri 20 Feb)

This lecture introduces the structure of the fins, limbs and muscles. The appearance of paired appendages and the origin of limbs with digits will form a major focus, and the lecture will also include a look at the consequences for the musculature.

5. Blood, Circulation and Breathing (Mon 23 Feb)

This lecture deals with blood circulation and breathing and how these have become changed and specialised throughout the evolution of vertebrates.

6. Sensory Systems (Wed 25 Feb)

This lecture looks at the evolution and adaptations of the nose, eyes, ears, lateral line and other sensory systems, following their development in the fossil record as far as possible.

Lectures 7 - 12
Dr Robert Asher

(e-mail rja58@cam.ac.uk, tel 36680)

References

Liem, K.F., Bemis, W.E., Walker, W.F. & Grande, L. (2001) 3rd Edition. *Functional Anatomy of the Vertebrates*, Harcourt College Publishers.

Kardong, K.V. (2001) 3rd Edition. *Vertebrates: Comparative Anatomy, Function, Evolution,* William C. Brown Publishers. [NB Page numbers given below are for the 3rd Edition].
The most suitable, single-volume, reference text. If you want to read a textbook before the course begins, read chapter three of Kardong.

Romer, A.S. & Parsons, T.S. (1985) 6th Edition. *The Vertebrate Body*, Saunders College Publishing.

7. Amniote diversity and reproduction (Fri 27 Feb)

The taxonomic and functional definition of "amniote"; components of the amniote egg and its evolutionary origin; strategies of reproduction across amniote clades.

Liem et al. (2001) chapter 21 and pp. 84-117, 142-146.

8. Constraint and development in the amniote circulatory system (Mon 2 Mar)

Heterochrony and the developmental template for descent with modification; embryongenesis of amniote circulation; adult circulatory patterns among amniotes and relation to metabolism.

Liem et al. (2001) Chapter 19

Gould & Lewontin (1979) "Spandrels of San Marco..." *Proceedings of the Royal Society of London Series B*, Biological Sciences 205 (1161), 581-598.

9. Hearing in amniotes (Wed 4 Mar)

Overview of hearing across amniotes; hearing in mammals; development, palaeontology and homology of the amniote ear and jaw.

Liem et al. (2001) Chapters 7, 12, 22.

Allin E.F. (1975) Evolution of the mammalian middle ear. *J. Morphology* 147(4): 403-437.

10. Feeding and digestion in amniotes (Fri 6 Mar)

Strategies for acquiring food across vertebrates; occlusion and food processing in mammals; development and morphology of teeth..

Liem et al. (2001) Chapters 16-17.

11. Amniote metabolism (Mon 9 Mar)

Endo- vs. Ectothermy among vertebrates; strategies for producing and regulating body temperature; torpor in endotherms.

Liem et al. (2001) pp. 82-83, 102, 645-651

Hillenius W.J. & Ruben J.A. (2004) The Evolution of Endothermy in Terrestrial Vertebrates: Who? When? Why? *Physiological and Biochemical Zoology* 77(6),1019–1042.

12. Endothermy in mammals and dinosaurs (including birds) (Wed 11 Mar)
How mammals and birds breathe; respiratory strategies for water and heat regulation; inferring activity pattern in extinct amniotes; circulatory implications of endothermy; metabolic consequences of large size.

Ruben, J. (1995). The evolution of endothermy in mammals and birds... Ann Rev Physiol 57:69-95.

O'Connor, P.M. & Claessens, L.P.A.M. (2005) Basic avian pulmonary design and flow-through ventilation in non-avian theropod dinosaurs. *Nature* 436: 253 – 256.

Practicals
Prof. Jenny Clack and Dr Robert Asher

1. How to build a vertebrate: from embyos to whole bodies.
In this section we will examine prepared histological slides of a frog neurula and a dogfish tail, as well as external features of selected cartilaginous fish and teleosts, and other relevant vertebrate specimens.
(Wed 18/Thu 19 Feb, repeated on Wed 25/Thu 26 Feb).

2. Amniote skull structure and the evolutionary homologies of mammalian ear ossicles.
Here, we will compare cranial anatomy in two groups of amniotes: turtles and mammals. In addition we will examine the fate of embryonic 1st and 2nd arch derivatives in histological sections of adult mammals.
(Wed 4/Thu 5 March, repeated on Wed 11/Thu 12 March)

Evolutionary Principles

Aims and Overview

This module will review the fundamental theories underlying evolutionary biology and consider the methods available to interpret, understand and predict the pattern and process of evolution. An understanding of evolutionary processes is of fundamental importance in Animal Biology. Here, we will investigate how organisms evolve at both phenotypic and genotypic levels, building up from models of evolution in populations to large-scale macroevolutionary patterns. We will examine the mechanisms of adaptation in populations involving single or multiple loci and how these can lead to predictions of future evolutionary change. The important topic of reproductive isolation among populations, and hence speciation, will also be considered. In the final series of lectures we will discuss the powerful methodology that has been developed to uncover phylogenetic relationships among organisms, and the patterns and processes of character evolution.

Dr Rufus Johnstone (RAJ)
(e-mail r.a.johnstone@zoo.cam.ac.uk, tel 36685)
Dr Nick Mundy (NM)
(email nim21@zoo.cam.ac.uk, tel 36657)

NOTE THE EARLY START THIS TERM

References

Ridley, M. (2004). *Evolution* 3rd Edition, Blackwell.
Futuyma, D. (1997) *Evolutionary Biology*, 3rd Edition, Sinauer.
Hartl, D. & Clark, A. (2007) *Principles of population genetics*, 4th Edition, Sinauer.

1. Population Genetics I (Wed 22 Apr) (NM)

Introduction to population genetics. Models of population genetics, genetic drift, mutation and population structure.

2. Population Genetics II (Fri 24 Apr) (NM)

Natural selection. Balance between evolutionary forces. Adaptive landscape. Multilocus population genetics.

3. Quantitative Genetics I (Mon 27 Apr) (NM)

Natural variation in quantitative traits. Basic model of quantitative genetics. Heritability.

4. Quantitative Genetics II (Wed 29 Apr) (NM)

Correlated traits. Genotype-environment interactions. Neutral forces in quantitative genetics. Quantitative trait loci.

5. Phenotypic Evolution I (Fri 1 May) (RAJ)

Long-term vs short-term evolution. Optimality and constraints.

6. Phenotypic Evolution II (Mon 4 May) (RAJ)

Game theory and evolutionary stability.

7. Phenotypic Evolution III (Wed 6 May) (RAJ)

Kin selection and kin recognition.

8. Speciation (Fri 8 May) (NM)

Species concepts. Modes of speciation. Mechanisms of reproductive isolation in allopatry, parapatry and sympatry.

9. Phylogenetic reconstruction (Mon 11 May) (NM)

Introduction to trees. Datasets for phylogenetic reconstruction. Distance methods. Parsimony methods. Likelihood methods.

10. Comparative method I (Wed 13 May) (RAJ)

Reconstruction of ancestral states. Parsimony and maximum likelihood.

11. Comparative method II (Fri 15 May) (RAJ)

Testing adaptive and evolutionary hypotheses. Independent contrasts.

12. Comparative method II (Mon 18 May) (RAJ)

Comparing phylogenies. Vicariance biogeography and coevolution.

Practicals
Dr Rufus Johnstone and Dr Nick Mundy

NOTE THE EARLY START THIS TERM

1. Population genetics
You will perform exercises on Hardy-Weinberg equilibrium, population structure and effective population size, and set up a computer simulation to study selection.
(Wed 22/Thu 23 Apr, repeated Wed 29 Apr/Thu 30 Apr).

2. Phylogenetic reconstruction and the comparative method
(Wed 6/Thus 7 May, repeated Wed 13/Thu 14 May).

Facilities

The Department of Zoology

More information about the Department of Zoology and its many activities may be found at the web site http://www.zoo.cam.ac.uk. Students are particularly welcome to attend seminars in the Department (see the web site and the notice boards, particularly the one on the first floor, near the Balfour Library).

The Balfour Library

10 good reasons to use the Department of Zoology's Balfour Library

1. 24/7 access
Apply for access using the grey form in your handbook.

2. Access to online library catalogues
Search for books and journals throughout the university, and renew your books on loan from any library in the university, online via *Newton* at http://www.lib.cam.ac.uk/newton/

3. Great facilities
PCs, photocopiers, printer, A3 size scanner, and power for laptops. Wireless network available.

4. Friendly and knowledgeable staff
Two full time librarians offer a continuous service throughout the day.

5. Amazing Special Collections
You are welcome to consult any of the 6,000 volumes dating from the fifteenth to the mid-twentieth century. The Eltringham African Collection is of particular use for undergraduate projects in African mammals and related subjects.

6. Recommended texts in print and online
We purchase all your recommended textbooks, many of which are available as e-books at http://www.lib.cam.ac.uk/electronicresources/ebooks.php

7. Access to electronic journals and databases (including Web of Science)
To find your reading and do your research, at eresources@cambridge http://www.lib.cam.ac.uk/electronicresources/

8. Lovely studying environment
The historic main reading room with its domed ceiling offers a pleasant place to study.

9. Informative website
Please visit the Balfour Library website for more detailed information on library facilities and services at http://www.zoo.cam.ac.uk/library/index.html. There are also printed guides in the library, which are available online via CamTools.

10. Things you need to do at the beginning of the Michaelmas term
Please report to the Library Office between 10:30am-12:30pm, or 3:30pm-4:30pm, Monday to Friday to:

- Attend a tour (upon request, for groups of 5 or more people)
- Register your University Card so you can borrow books
- Buy a photocopying card

We look forward to seeing you in the Balfour Library soon! Clair Castle, Librarian, and Jane Acred, Assistant Librarian

The Museum of Zoology

The University of Cambridge Museum of Zoology (UMZC) is open to the public and to students from 9.45 to 4.45 each weekday. Its exhibits are designed to complement undergraduate studies, and contain a wealth of material relevant to the IB Animal Biology course. You are strongly recommended to visit. Some parts of the course may include guided visits to parts of the exhibition halls.

The permanent display aims to show at least one specimen of every group of animal, both fossil and living, that the Museum holds. In this way, a large and comprehensive part of the Museum's collection is represented by the displays.

The specimens on display are used for undergraduate teaching, so the gallery layout and the majority of the accompanying text relates to the anatomy of the specimens and their evolutionary relationships. The smaller, simpler organisms and the earlier vertebrates are on the first level, moving through to the birds and mammals in the lower gallery.

The UMZC collections date back to 1814 when the Harwood Collection of Comparative Anatomy was bought by the University. Several other important collections were added later, including the Swainson Collection of birds and the zoological collection of the Cambridge Philosophical Society; the latter included many specimens collected by Charles Darwin. In 1865 the Museum moved into a new building on the New Museums Site. The bulk of the existing collections were accumulated between 1865 and 1915. Many private collections of shells, insects, and birds were bought or donated, while expeditions brought back collections of insects, of marine invertebrates from the Indian Ocean, of fresh water fish and amphibians from Africa, and of mammals and birds from South East Asia and Australia. During the 1930s important collections of fossil fish from Scotland and Canada, of fossil reptiles from Africa, and (by exchange) of fossil mammals from North America were acquired.

People - and how to contact them

E-mail addresses and telephone numbers may be accessed via the departmental web page http://www/zoo.cam.ac.uk or may be found in the University lookup service. A number of key assistant staff may be contacted via Reception.

Head of Department	Malcolm Burrows, Rooms F18/S30, 36601/36628
Deputy Head of Department (Teaching)	William Foster, Insect Room, 36615
Teaching Secretary	Rachel Aucott, Room F1, 69017
Departmental Administrator	Julian Jacobs, Room F12, 36621
Accounts Office	Simon Beeton, Room F10, 36646
Facilities Manager	Ian Goldstone, Room F3
Library	Clair Castle, assisted by Jane Acred, 36648
Reception	Linda Blades, 36600
First-aiders	To be contacted via Reception, 36600 Outside Office hours, tel. 101 Ambulance, tel. 1999
Neal Maskell and Nanna Evers	Elementary laboratory facilities
Nigel Hall	Keys and entry cards
Normal staff working hours	8.30 am to 1.00 pm and 2.00 to 5.00 pm Monday to Friday, inclusive
Tea room opening hours	10.00 to 11.15 am and 3.00 to 4.15 pm Monday to Friday inclusive
Balfour Library	Information on the Library is detailed on the previous pages.

Teaching Staff

Professors

M E Akam	(Evolution & Diversity) *[Director of The Museum]*
W Amos	(Behavioural Ecology)
A P Balmford	(Population & Community Ecology)
C M Bate	(Developmental Biology)
P P G Bateson	(Behaviour & Behavioural Neuroscience)
M Burrows	(Neurobiology) *[Head of Department]*
J A Clack	(Evolution & Diversity)
T H Clutton-Brock	(Behavioural Ecology)
N B Davies	(Behavioural Ecology)
C P Ellington	(Animal Physiology)
R E Green	(Population & Community Ecology)
S P Jackson	(Cell Biology)
E B Keverne	(Behaviour & Behavioural Neuroscience)
R A Laskey	(Cell Biology)
S B Laughlin	(Neurobiology)
S Maddrell	(Animal Physiology)
P Simpson	(Developmental Biology)

J C Smith	(Cell Biology)
W Sutherland	(Population & Community Ecology)

Readers

B G Hedwig	(Neurobiology)
H L B Skaer	(Developmental Biology)
R A Johnstone	(Behavioural Ecology)

University Senior Lecturers

R S K Barnes	(Population & Community Ecology)
W A Foster	(Evolution & Diversity)

University Lecturers

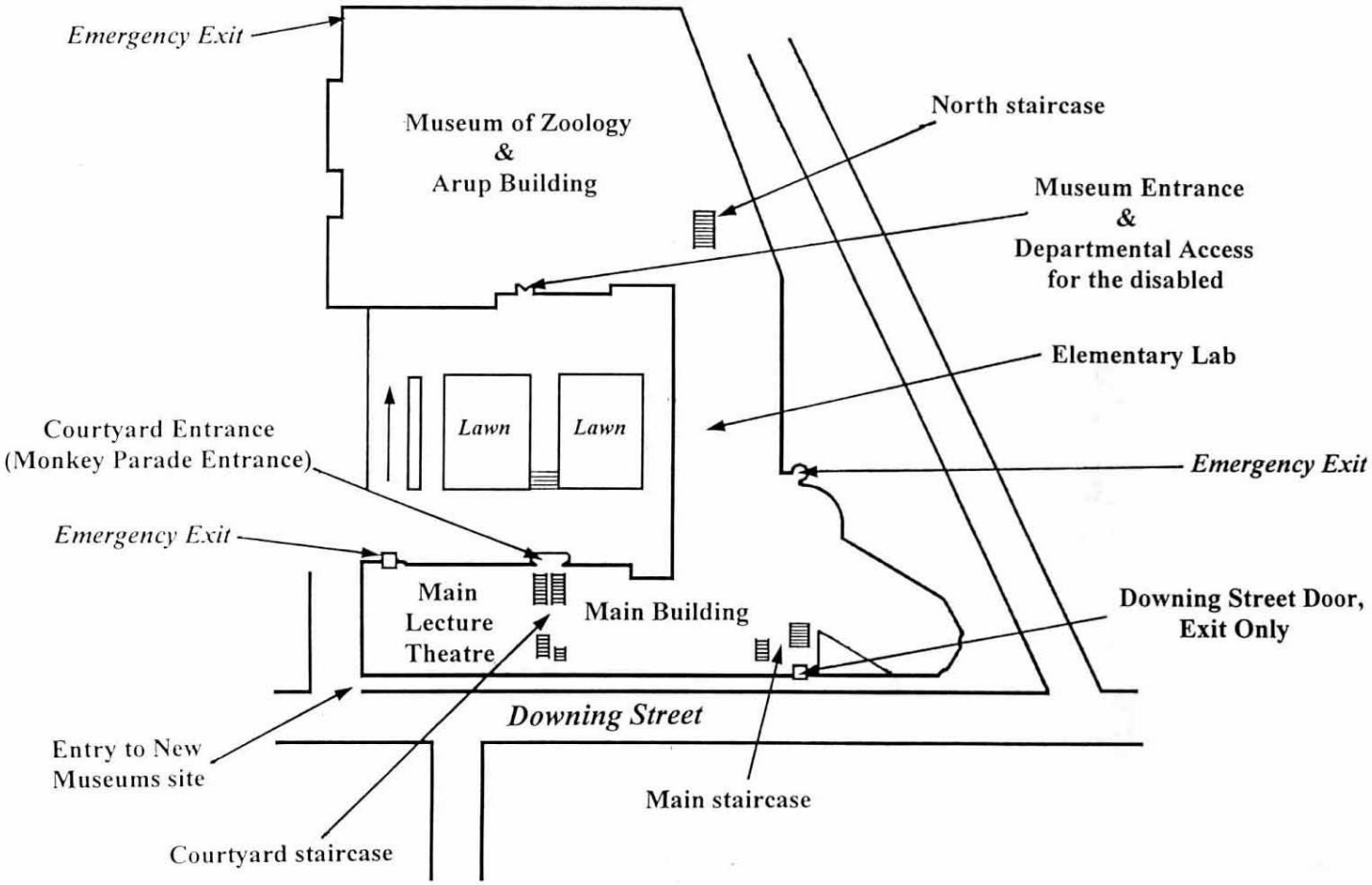
R J Asher	(Evolution And Diversity)
H Baylis	(Cell Biology)
W Federle	(Animal Physiology)
C Jiggins	(Evolution &Diversity)
R M Kilner	(Behavioural Ecology)
T Krude	(Cell Biology)
A Manica	(Population & Community Ecology)
B J Mccabe	(Behaviour & Behavioural Neuroscience)
N Mundy	(Behavioural Ecology)

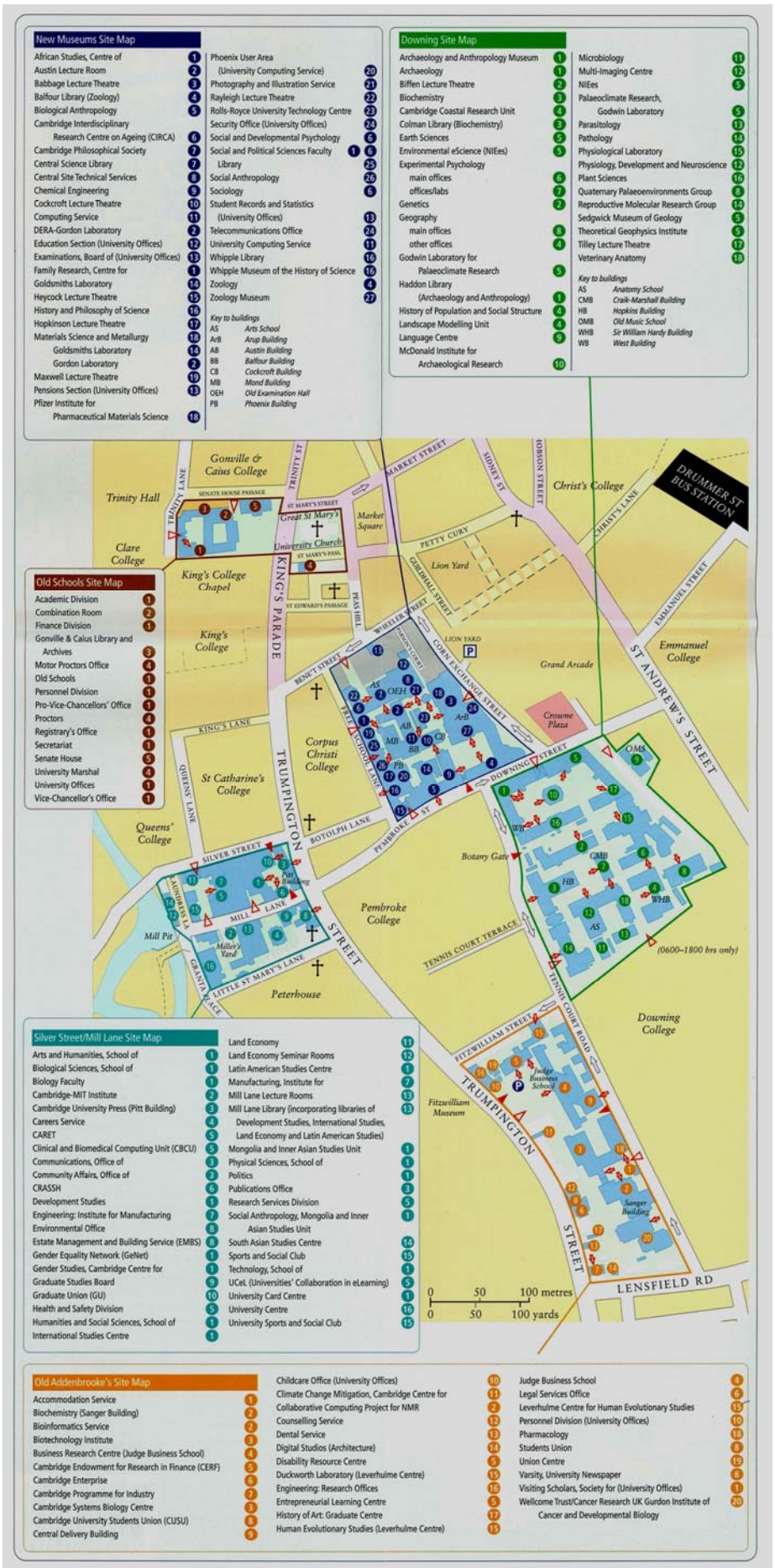
R C Preece	Senior Assistant Curator In Malacology

Location of teaching and departmental facilities

Main lecture theatre	Ground floor, access via courtyard entrance
Part II lecture theatre	First floor, access via courtyard stairs
Elementary laboratory	Ground floor, access via courtyard or Museum entrance
Seminar room	First floor, room F11
Balfour library	First floor
Basement conference room	Basement
Tea room	Second floor, above Library
First-aid room	First floor, next to seminar room
Reception	Ground floor access via courtyard entrance

Drink dispensing machines	Museum entrance foyer (hot drinks) Basement, via courtyard entrance (cold drinks)
Departmental Administrator	First floor, room F12
Head of Department	First floor, room F18
Wheelchair access	Via ramp at Museum entrance. Please use telephone in the Museum foyer to contact Reception to arrange access.
Toilets	Wheelchair access to toilets in the Museum basement and first floor of Downing Street building, opposite Purchasing Office. Basement of Downing Street building, downstairs from courtyard entrance. Second floor, between Arup and Downing Street building, near north staircase.


Emergency Exit
Museum of Zoology
&
Arup Building
North staircase
Museum Entrance
&
Departmental Access
for the disabled
Elementary Lab
Lawn
Lawn
Courtyard Entrance
(Monkey Parade Entrance)
Emergency Exit
Emergency Exit
Main
Lecture
Theatre
Main Building
Downing Street Door,
Exit Only
Downing Street
Entry to New
Museums site
Main staircase
Courtyard staircase


New Museums Site Map
African Studies, Centre of 1
Austin Lecture Room 2
Babbage Lecture Theatre 3
Balfour Library (Zoology) 4
Biological Anthropology 5
Cambridge Interdisciplinary Research Centre on Ageing (CIRCA) 6
Cambridge Philosophical Society 7
Central Science Library 7
Central Site Technical Services 8
Chemical Engineering 9
Cockcroft Lecture Theatre 10
Computing Service 11
DERA-Gordon Laboratory 2
Education Section (University Offices) 12
Examinations, Board of (University Offices) 13
Family Research, Centre for 1
Goldsmiths Laboratory 14
Heycock Lecture Theatre 15
History and Philosophy of Science 16
Hopkinson Lecture Theatre 17
Materials Science and Metallurgy 18
Goldsmiths Laboratory 14
Gordon Laboratory 2
Maxwell Lecture Theatre 19
Pensions Section (University Offices) 13
Pfizer Institute for Pharmaceutical Materials Science 18
Phoenix User Area (University Computing Service) 20
Photography and Illustration Service 21
Rayleigh Lecture Theatre 22
Rolls-Royce University Technology Centre 23
Security Office (University Offices) 24
Social and Developmental Psychology 6
Social and Political Sciences Faculty 1 6
Library 25
Social Anthropology 26
Sociology 6
Student Records and Statistics (University Offices) 13
Telecommunications Office 24
University Computing Service 11
Whipple Library 16
Whipple Museum of the History of Science 16
Zoology 4
Zoology Museum 27
Key to buildings
AS Arts School
ArB Arup Building
AB Austin Building
BB Balfour Building
CB Cockcroft Building
MB Mond Building
OEH Old Examination Hall
PB Phoenix Building
Downing Site Map
Archaeology and Anthropology Museum 1
Archaeology 1
Biffen Lecture Theatre 2
Biochemistry 3
Cambridge Coastal Research Unit 4
Colman Library (Biochemistry) 3
Earth Sciences 5
Environmental eScience (NIEes) 5
Experimental Psychology
main offices 6
offices/labs 7
Genetics 2
Geography
main offices 8
other offices 4
Godwin Laboratory for Palaeoclimate Research 5
Haddon Library (Archaeology and Anthropology) 1
History of Population and Social Structure 4
Landscape Modelling Unit 4
Language Centre 9
McDonald Institute for Archaeological Research 10
Microbiology 11
Multi-Imaging Centre 12
NIEes 5
Palaeoclimate Research, Godwin Laboratory 5
Parasitology 13
Pathology 14
Physiological Laboratory 15
Physiology, Development and Neuroscience 17
Plant Sciences 10
Quaternary Palaeoenvironments Group 8
Reproductive Molecular Research Group 14
Sedgwick Museum of Geology 5
Theoretical Geophysics Institute 5
Tilley Lecture Theatre 17
Veterinary Anatomy 18
Key to buildings
AS Anatomy School
CMB Craik-Marshall Building
HB Hopkins Building
OMB Old Music School
WHB Sir William Hardy Building
WB West Building
Old Schools Site Map
Academic Division 1
Combination Room 2
Finance Division 1
Gonville & Caius Library and Archives 3
Motor Proctors Office 4
Old Schools 1
Personnel Division 1
Pro-Vice-Chancellors' Office 1
Proctors 4
Registrary's Office 1
Secretariat 1
Senate House 5
University Marshal 4
University Offices 1
Vice-Chancellor's Office 1
Gonville & Caius College
Trinity Hall
Clare College
King's College Chapel
King's College
Queens' College
St Catharine's College
Corpus Christi College
Pembroke College
Peterhouse
Christ's College
Emmanuel College
Downing College
Fitzwilliam Museum
Great St Mary's University Church
Market Square
Lion Yard
Grand Arcade
Crowne Plaza
Botany Gate
Mill Pit
Miller's Yard
Tennis Court Terrace
Judge Business School
Sanger Building
DRUMMER ST BUS STATION
TRUMPINGTON STREET
KING'S PARADE
ST ANDREW'S STREET
DOWNING STREET
TENNIS COURT ROAD
LENSFIELD RD
0 50 100 metres
0 50 100 yards
(0600–1800 hrs only)
Silver Street/Mill Lane Site Map
Arts and Humanities, School of 1
Biological Sciences, School of 1
Biology Faculty 1
Cambridge-MIT Institute 2
Cambridge University Press (Pitt Building) 3
Careers Service 4
CARET 5
Clinical and Biomedical Computing Unit (CBCU) 5
Communications, Office of 3
Community Affairs, Office of 2
CRASSH 6
Development Studies 1
Engineering: Institute for Manufacturing 7
Environmental Office 8
Estate Management and Building Service (EMBS) 8
Gender Equality Network (GeNet) 1
Gender Studies, Cambridge Centre for 1
Graduate Studies Board 9
Graduate Union (GU) 10
Health and Safety Division 5
Humanities and Social Sciences, School of 1
International Studies Centre 1
Land Economy 11
Land Economy Seminar Rooms 12
Latin American Studies Centre 1
Manufacturing, Institute for 7
Mill Lane Lecture Rooms 13
Mill Lane Library (incorporating libraries of Development Studies, International Studies, Land Economy and Latin American Studies) 13
Mongolia and Inner Asian Studies Unit 1
Physical Sciences, School of 1
Politics 1
Publications Office 1
Research Services Division 5
Social Anthropology, Mongolia and Inner Asian Studies Unit 1
South Asian Studies Centre 14
Sports and Social Club 15
Technology, School of 1
UCeL (Universities' Collaboration in eLearning) 5
University Card Centre 1
University Centre 16
University Sports and Social Club 15
Old Addenbrooke's Site Map
Accommodation Service 1
Biochemistry (Sanger Building) 2
Bioinformatics Service 2
Biotechnology Institute 3
Business Research Centre (Judge Business School) 4
Cambridge Endowment for Research in Finance (CERF) 5
Cambridge Enterprise 6
Cambridge Programme for Industry 7
Cambridge Systems Biology Centre 3
Cambridge University Students Union (CUSU) 8
Central Delivery Building 9
Childcare Office (University Offices) 10
Climate Change Mitigation, Cambridge Centre for 11
Collaborative Computing Project for NMR 2
Counselling Service 12
Dental Service 13
Digital Studios (Architecture) 14
Disability Resource Centre 5
Duckworth Laboratory (Leverhulme Centre) 15
Engineering: Research Offices 16
Entrepreneurial Learning Centre 5
History of Art: Graduate Centre 17
Human Evolutionary Studies (Leverhulme Centre) 15
Judge Business School 10
Legal Services Office 11
Leverhulme Centre for Human Evolutionary Studies 2
Personnel Division (University Offices) 12
Pharmacology 13
Students Union 14
Union Centre 5
Varsity, University Newspaper 15
Visiting Scholars, Society for (University Offices) 16
Wellcome Trust/Cancer Research UK Gurdon Institute of Cancer and Developmental Biology 5

Natural Sciences Tripos 2008/9 Part IB Animal Biology Examinations and Practical Assessment

Theory papers

There will be two theory papers, each of three hours' duration. Each paper will include questions on each of the five half-term sections of the course.

Paper 1

This will contain five sections representing each half-term section of the course. Candidates will be required to attempt questions from four sections. Each section will consist of two essay-style questions, and candidates may attempt only one from any section. Each question will carry equal weight. Candidates should not assume that there will be an essay from each of the two lecture blocks within each question. Some questions may require knowledge of material from more than one half-term section of the course.

Paper 2

Theory Paper 2 will contain five sections, and each section will consist of either one or several questions. Each section will carry equal weight. All questions must be answered. They may require the design, analysis or interpretation of investigations relevant to the topics covered in the lectures.

Practical assessment

1. Practical assessment will be continuous throughout the year and will contribute to your examination mark. There will be no practical examination at the end of the year. The main features of the assessment scheme are as follows:

2. Each of the five half-term sections of the course will account for 4% of the Tripos marks, so that overall the practical assessment will correspond to 20% of the total mark.

3. **The two practicals in each of the five sections of the course will be marked on a scale of A, B, C and D (see verbal descriptors on the scheme on page 2, below).** The marking may be done first by a demonstrator, but the member of staff in charge of the practical will give the final, recommended mark, which you will be shown. The recommended mark will be passed on to the Examiners. The marked work will be returned so that you will have an opportunity to discuss your write-up with the marker should you need to.

4. Where possible, you should try to write up during the practical period. However, in some cases, parts of the practical write-up may be completed later. In such cases you will be advised of this by the practical organiser. Write-ups should be handed in to Reception, where the student will also acknowledge this with her/his signature, by **4 pm on the Monday following the practical**, unless advised differently by the organizer. **Late submissions will not be accepted without a supporting letter from your Director of Studies.**

5. You will be given specific guidance about the form and length of practical reports as appropriate when each section of the course begins. In general, a long write-up is not expected and, as a rough guide, the text (excluding graphs and diagrams) **should normally occupy less than two-sides of A4.** Write clear, succinct reports: verbosity will not be rewarded. Where illustrations are required, credit will be given for accuracy and clarity of information rather than artistic merit.

6. If you do not complete the write-up during the practical, you should not spend more than one hour on it outside normal class time.

7. The marks given to write-ups count towards the examination result. **It is therefore essential that write-ups are the independent efforts of individual students.** In some practicals students may work in pairs, but the write-ups must nevertheless be completed independently. Where practical work is carried out in pairs, the name of the practical partner must be declared at the top of the write-up: if an assessor believes that a write-up has not been achieved independently, that write-up will be returned unmarked and the case will be referred to the examiners.

8. If you are prevented from attending a practical class you should, in the first opportunity, consult the member of staff running the class. If an absence could affect your examination result, a letter from your Director of Studies may be required.

9. The examiners reserve the right to ask for practical submissions to be handed in at the end of the year for their inspection. **You should therefore keep your write-ups when they are returned to you.**

Part IB Animal Biology Practicals 2008/9
Marking Scheme

A Outstanding

Excellent insight into the practical aims; exceptionally good organisation and presentation; critical treatment of the results. The Discussion would be very clearly written and show evidence of originality.

B Good

Full understanding of the practical aims; coherent organisation; clear presentation; accurate answers to the questions. The Discussion would be a complete and critical response to the prompts and questions in the handout.

C Satisfactory

Good in parts, but important points omitted. Might also have defects in presentation or be not very well written. Reasonably competent, but might show misunderstanding of the material: significant inaccuracies or errors.

D Poor

Some knowledge of the material is evident, but there are serious deficiencies in understanding, organization, clarity or accuracy. Write-ups that are unduly brief would fall into this category.

N.B. A mark of grade 'B' is the one that is generally most frequently given, and it corresponds, as the descriptor above indicates, to a complete, coherent, correct, clear and critical write-up. A mark of grade 'A' is, therefore, exceptional, and is much less frequently given.

Tripos examination papers, 2008
(previous years' papers are available on CamTools)

NATURAL SCIENCES TRIPOS PART 1B

27th May 2008 9 to 12

ANIMAL BIOLOGY (1)

*Answer **four** questions; candidates may attempt only **one** from any Section.*
*Write your **examination number** on the first sheet of each answer.*
The answer to each question must be tied up separately, with its own cover-sheet.
*Write on **one** side of the paper only.*

Section A **Behaviour and Ecology**

1. How does an analysis of trade-offs help us to understand behaviour?

2. Does understanding the mechanisms causing behaviour help us to understand its function?

Section B **Brains and Behaviour**

3. What is the evidence that nervous systems are constrained by costs?

4. How does an animal generate rhythmical movements?

Section C **Insect Biology**

5. Discuss the role of kin selection in the evolution of eusociality in insects.

6. Discuss the hypothesis that an insect's body size is limited by its specific type of respiration.

Section D **Vertebrate Evolutionary Biology**

7. Describe the features you would expect to have been present in an ancestral chordate. Among living basal chordates, which group do you consider to be most closely related to craniates and why?

8. Describe strategies used by vertebrates in regulating body temperature and discuss examples in which body temperature varies periodically.

Section E **Evolutionary Principles**

9. How are phylogenies inferred and what are their uses?

10. How and why do animals identify their kin?

END OF PAPER

NATURAL SCIENCES TRIPOS PART IB

30th May 2008 9.00 to 12.00

ANIMAL BIOLOGY (2)

*Answer all **seven** questions.*

***Each Section** carries equal weight.*

Where there are questions within a section, each question carries equal marks.

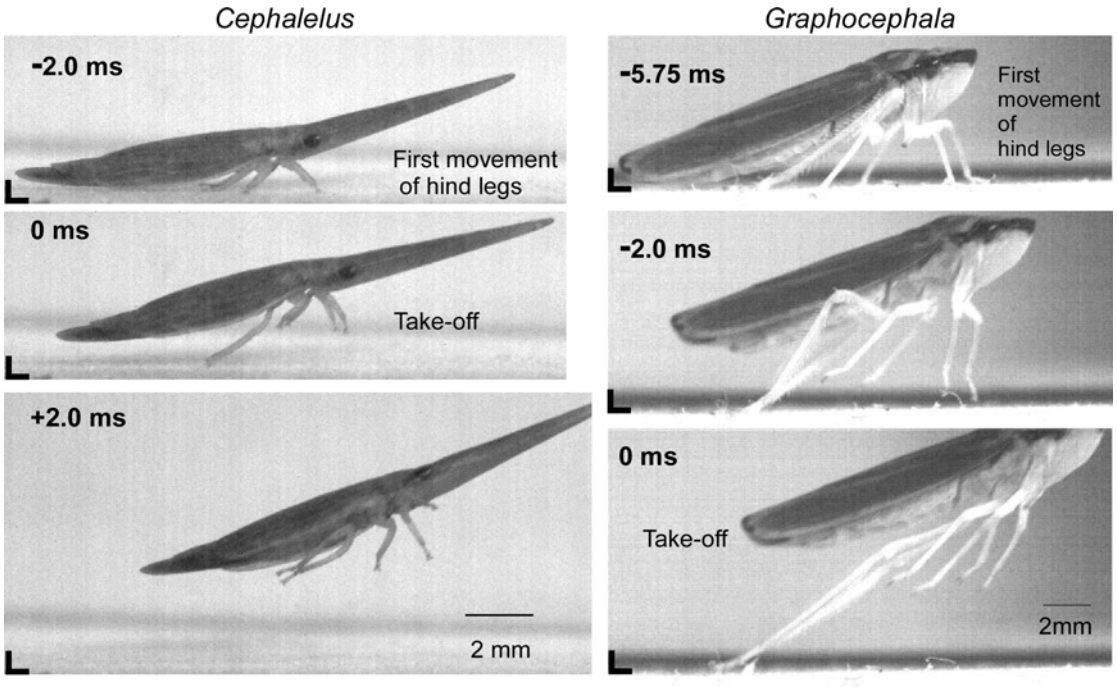
Where there are sub-sections in a question, the sub-sections carry equal marks.

*Write your **examination number** on the first sheet of the answer to **each question**.*
The answer to each question must be tied up separately, with its own cover-sheet.
*Write on **one** side of the paper only.*

Section A **Behaviour and Ecology**

1. In spring, one year old female blackbirds start their clutches, on average, ten days later than older females. Suggest two hypotheses to explain this. Outline a research programme to test these hypotheses.

Section B **Brains and Behaviour**



	Body mass, mg	Hind Tibia, mm	Hind Femur, mm	Ratio of leg lengths		
				Front	Middle	Hind
Cephalelus	9	1.3	0.8	1	1.1	1.4
Graphocephala	13	4	2	1	1.2	2.9

2.a) The two columns of three images taken at the times indicated (take-off = 0 ms) show the jumping behaviour of two species belonging to the same family of leafhoppers (Insecta, Hemiptera). Both propel their bodies by movements of the hind legs.

The table shows the average mass, body length and the ratio of leg lengths of the two species.

i) What is the take-off velocity of each species?
ii) How long does each species take to accelerate its body to take-off?
iii) Can muscle contractions generate these movements in the time available?
iv) What is the effect of hind leg length on jumping performance?
v) Why do animals jump?

2.b) Recordings were made from single afferent axons in the cochlear nerve of a small nocturnal rodent. Threshold sound pressure levels were measured in decibels at a number of frequencies. The results for three axons are given in the following table.

	20 kHz	22 kHz	24 kHz	26 kHz	28 kHz	30 kHz	32 kHz
Axon 1	95	92	70	10	68	90	92
Axon 2	55	20	30	60	80	90	95
Axon 3	95	92	97	55	22	25	40

What behaviours might the cochlea of this species be specialised for?

Which of these behaviours is the most likely, and why?

Very briefly, outline the types of experiment you would conduct to

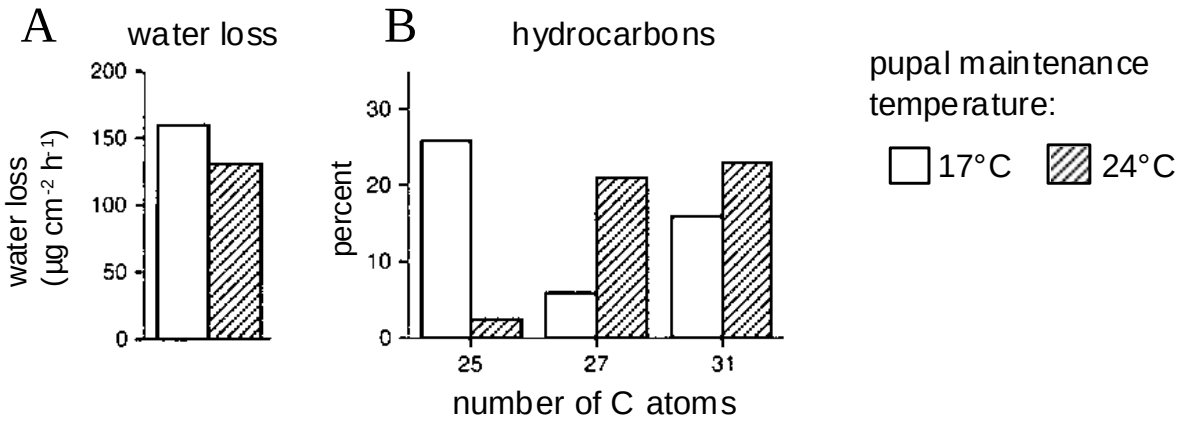
i) Discover the auditory behaviour for which this cochlea is specialised.
ii) Determine how this cochlea is specialised.

Section C **Insect Biology**

3. Waterbugs of the family Belostomatidae include some of the largest insects in the world. They are carnivores, feeding on fish, frogs and tadpoles. The female lays the eggs, each of which is quite large, on the back of the male. The male looks after the eggs by staying near or just above the water surface, constantly moistening the eggs.

a) Why do eggs require parental care?
b) Why do males, rather than the females care for the eggs?
c) Suggest experiments that you might carry out to establish why parental care is carried out by the males.

4.



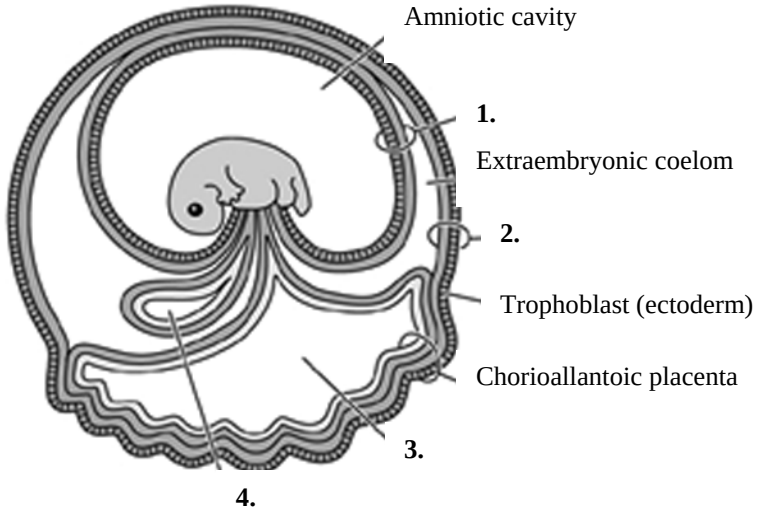
The graphs show the effect of pupal thermal regime on adult water loss rates and cuticular hydrocarbon composition in *Drosophila.* (A) Water loss of adult flies (at 25°C, 5% RH, flies killed using cyanide). The pupae of these flies had been maintained at either 17 or 24°C (larvae reared at 17°C). (B) amounts of cuticular surface hydrocarbons for the same flies.

a) Describe and interpret the effect shown by these graphs.
b) How do you expect the water balance to change from a resting to a flying fruit fly?

Section D **Vertebrate Evolutionary Biology**

5. List the three main types of vertebrate hard tissue and draw up a table indicating the embryonic origin of each and the structures that it forms in the vertebrate body.

6. Given the diagrammatic representation below of a developing embryo of a placental mammal, identify the four extraembryonic membranous structures numbered 1-4. State briefly how the reproductive strategies of marsupials and placentals differ in terms of gestation length, foetal development and maternal investment.



Section E **Evolutionary Principles**

7. Dark coat colour in a species of mouse is a Mendelian trait controlled by a locus with two alleles. The dark allele, *D*, is dominant to the pale allele, *d*. In two parapatric populations of the species, dark mice are more common in population A than population B.

a) i) The frequency of dark mice in population A is 84%.
Assuming the population is in Hardy-Weinberg equilibrium (HWE), what are the allele and genotype frequencies in population A?

ii) The frequencies of genotypes in population B are:

DD	*Dd*	*dd*
0.10	0.20	0.70

What are the frequencies of coat colour phenotypes and alleles in population B?
What would be the expected genotype frequencies in population B if they were at HWE?

b) Discuss the possible causes of the differences in allele frequency between populations A and B.

c) Calculate the F_{ST} for the coat colour locus between populations A and B from the relationship $F_{ST} = (H_T - H_S) / H_T$

where H_T = expected heterozygosity for the total population of A and B
(assume equal population size for A and B)
H_S = average heterozygosity of populations A and B

The average F_{ST} at a series of neutral loci among populations A and B is 0.05. What can you infer by comparing this value to the F_{ST} value that you just calculated at the coat colour locus?

What to do in an emergency

You should familiarise yourself with:

1 The fire evacuation procedure.

2 The location of fire exits and emergency call points (break glass).

3 The location of first aid boxes and how to contact first-aiders. This information is posted with each first-aid box.

Copies of the departmental Safety Handbook are available for consultation in the Elementary and Experimental laboratories.

UNIVERSITY OF
CAMBRIDGE

UNIVERSITY SECURITY CONTROL CENTRE

NEW MUSEUMS SITE

TELEPHONE :
ROUTINE CALLS - (3) 31818
EMERGENCY CALLS - 101

- Serious Incident/Emergency
- Anything suspicious
- Anyone acting suspiciously

CONTACT:

- **Departmental Supervisor**

and/or

- **University Security Control Centre**

Routine calls - **(3) 31818**

Emergency calls - **101**