Natural Sciences Tripos

Part II Psychology, Neuroscience and Behaviour

2017 - 2018
NST Part II Psychology, Neuroscience and Behaviour

Subject Summary:

The neurosciences are one of the most exciting and fast moving areas in biology and these features are well represented in this interdepartmental course. Neurosciences are noted for the breadth of their theoretical base in diverse areas of modern biology and in the range of their medical and social applications. In particular, neuroscience draws its creativity from the integration of different levels of analysis that transcend the boundaries of traditional disciplines and individual departments: from the molecular events taking place within cells, through the electrical and chemical interactions between cells in the nervous system, to the integrated behaviour of the whole organism, including humans. This course provides an integrated treatment of the neurosciences, and is built around lectures and a research project.

Lectures are organised in modules of 24 lectures drawn from existing Part II modules offered by Psychology, PDN and Zoology, sometimes with additional input from other Departments. Each module will be delivered within a single term (either Michaelmas or Lent) at a rate of three lectures per week for each module. Students must attend four modules in total. There are no restrictions on choice of modules because they will be timetabled to ensure no clashes between them.

In addition, students complete a two term experimental project in the laboratory of an individual supervisor based in one of the contributing departments or elsewhere in the Cambridge Neuroscience Community.

The course is best suited for students who have studied some neurobiology in Part IB, either in MVST or in NST, but others will be able to take it if they are prepared to do some background reading.

NST Part II Biological and Biomedical Sciences (BBS) taking Psychology, Neuroscience and Behaviour

No experimental project is required for students taking Psychology, Neuroscience and Behaviour as part of BBS and so it will recommend itself to those who do not plan a career in experimental science. Candidates choose any four modules and, in addition, read a minor subject and write a dissertation.
Applying for Part II Courses

Applications

During the Easter vacation, College Directors of Studies ask their students to choose their Part II subjects. The allocation of students to courses takes place at the end of the Easter Term. Later admission is sometimes possible. Contact your College Tutorial Office or your Director of Studies for further information.

Admissions

Part II Psychology, Neuroscience and Behaviour is restricted in their student numbers. In some years, more people may apply than can be accommodated. This means that we have had to be selective and regrettably not everyone who applies will obtain a place. We select applicants on the basis of their overall marks in Part IB. Candidates with complicating or extenuating circumstances may be interviewed individually. We make every effort to accommodate everybody who has a strong motivation and interest in the subject.

Contacts

If you have any further queries about Part II Psychology, Neuroscience and Behaviour that are not answered here, please contact one of the following:

Dr David Belin bdb26@cam.ac.uk
Dr David Parker dip27@cam.ac.uk
Dr Nick Mundy djp27@cam.ac.uk
Description of Modules

We anticipate each of the following modules will be available in 2016-2017, although more modules may become available and some modules may be subject to minor changes. Details are correct at the time of going to press.

Michaelmas Term Modules

Colour code:
Blue: Offered by Psychology
Purple: offered by PDN
Black: offered by Zoology

✔ Motivation, Judgement and Decision Making
Offered by Psychology (Section A)

Module organiser: Dr David Belin (bdb26@cam.ac.uk)

This module takes different approaches to the question of behavioural control – why we take some actions, avoid taking others; do what we are supposed to do and what is best for us and do things that are clearly harmful. Some behaviours are simply elicited by the environment and others might be thought to serve regulatory needs, but most are too complex to be explained in simple terms. The module provides you with a range of approaches in current psychology, from behavioural neuroscience to purely psychological or cognitive research and demonstrates potential applications to real world issues.

✔ Developmental Neurobiology
Offered by PDN (Module N1) maximum of 80 students

Module organiser: Prof. Roger Keynes (rjk10@cam.ac.uk)

This module addresses how nerve cells in an embryo manage to assemble into the sophisticated information-processing system that is the brain. We now understand a considerable amount about these processes, while many fascinating questions remain. Professor Bill Harris begins the module by discussing how genetically-encoded information specifies the origins of different types of nerve cells and different parts of the nervous system, and giving examples of the sophisticated experimental approaches that are now used. We then examine the process of neural induction that forms the early neural tube in vertebrates. Once nerve cells have formed, they have to extend axons to the correct targets to ‘wire up’ the nervous system, as will be considered by Professor Christine Holt and Dr Geoff Cook. Axons then have to make synapses, in a manner that will generate functional neural networks, as Drs Matthias Landgraf and Matthew Oswald will explain.

Interspersed with these lectures on processes of general applicability are others that focus on specific systems of key importance. Dr Steven Moore reviews the development of the cerebral cortex, showing how all the mechanisms considered so
far combine to generate the most advanced part of the human brain. Professor Ole Paulsen will discuss the mechanisms of synaptic plasticity that operate in the mature cortex and underlie learning and memory. Dr Stephen Eglen gives a computational scientist’s view of how topographic maps are formed and tuned, with special reference to the visual system. Finally, to illustrate how the processes of development and evolution interact, Dr Clare Baker reviews this in relation to electoreception.

The course is best suited for students who have studied some neurobiology in Part IB, either in MVST or in NST, but others will be able to take it if they are prepared to do some background reading.

✔️ **Molecular and Cellular Neuroscience**  
Offered by PDN (Module N2) *maximum of 40 students*  
*Module organiser: Dr David Parker ([dip27@cam.ac.uk](mailto:dip27@cam.ac.uk))*  

While many approaches are applied to analyses of nervous systems, it is obviously important to understand the cellular and synaptic properties underlying sensory, motor, and cognitive functions. The voltage-dependent ion channels that determine the resting and active properties of neurons form a superfamily of at least 143 genes, with further functional diversity resulting from alternative splicing, posttranslational modifications, and the plasticity of varying combinations of subunits that form channels. This results in a massive range of potential cellular properties (e.g. adaptation, tonic spiking, bursting, post-inhibitory rebound, plateau potentials). At the synaptic level there is estimated to be in excess of 200 transmitter substances, each of which can differ in the mechanisms of their release and their effects. These transmitter substances can also interact to evoke effects that cannot be predicted from their individual actions.

This module provides a general basis from which you can investigate various aspects of cellular and synaptic function. The lectures will cover ion channels, oligodendrocytes and glial cells, ionotropic transmitter receptors including NMDA and AMPA-type glutamate receptors, Cys-loop receptors (e.g. nicotinic acetylcholine), G protein-coupled receptors, the role of calcium in synaptic transmission and plasticity, and mechanisms of transmitter release and activity-dependent and neuromodulator-evoked plasticity. Knowledge of these effects will provide a basis for understanding the cellular mechanisms of effects covered in other neuroscience modules.

✔️ **Sensory Transduction**  
Offered by PDN (Module N4)  
*Module organiser: Dr Hugh Matthews ([hrm1@cam.ac.uk](mailto:hrm1@cam.ac.uk))*  

The process of transduction within individual sensory receptors has consequences for, and imposes limits on, the perception of sensory events. Considerable advances have been made in recent years in elucidating the means by which primary sensory stimuli are transduced and processed. The module begins by examining the molecular mechanisms which enable vertebrate photoreceptors to respond with incredible sensitivity to individual photons of light, yet which also allow the cells to recover rapidly and to respond effectively at high light intensities. This will be followed by consideration of invertebrate phototransduction, which will include the ever-more-widespread roles of TRP channels which were originally discovered in this system. The modality then shifts to the chemical senses, to discuss transduction and coding in
olfactory receptors, which share some fascinating features in common with phototransduction, as well as exhibiting some marked differences. The focus then switches to mechanotransduction, especially the encoding of auditory information in both vertebrate and invertebrate species. These special senses will be contrasted with the molecular and cellular mechanisms responsible for the transduction of pain.

✔ Neuroethology: The Neural Basis of Adaptive Behaviour

Offered by Zoology (Module M4)
Module organiser: Dr Berthold Hedwig (bh202@cam.ac.uk)

This module places a strong emphasis on understanding the neural mechanisms underlying behaviour. The lectures explore how nervous systems are organised, how animals gather and process information about the environment, and how they generate the motor activity underlying their behaviour. The first lectures will give an introduction into the organisation and adaptations of brains and will show how an animal's capabilities are linked to ecology and lifestyle. We then consider neural circuits and the control of motor patterns, animals performing at extremes allow to analyse specific neuronal adaptations. We demonstrate how auditory and visual processing is adapted to the lifestyle in insects and other species. Larval and adult Drosophila will be discussed with an emphasis on genetic techniques to study their nervous system and behaviour. Finally, we will demonstrate the basis of plasticity in neural networks and behaviour at a circuit and cellular level.

✔ Evolution and Behaviour: Genes and Individuals

Offered by Zoology (Module M5)
Module organiser: Prof Rebecca Kilner (rmk1002@cam.ac.uk)

The classical way to study animal behaviour separates questions concerned with function (what is the adaptive value of the behaviour? what is its evolutionary history?) from those focused on causation (how is the behaviour controlled? how does it develop during a lifetime?). The aim of this course to show how recent research is sweeping aside these traditional distinctions in two different ways, yielding new insights into the way that evolution works. Specifically:

1) Animal behaviour, and the mechanisms by which it develops, can contribute to evolutionary change: by changing ecological conditions; by imposing selection on other parts of the phenotype and other individuals; by influencing patterns of inherited variation; and by facilitating reproductive isolation.
2) At the same time, the mechanisms controlling behaviour and its development are themselves subject to natural selection and are adaptations for the ecological conditions in which an animal lives. This means that we can predict the particular mechanisms involved in behavioural development, as well as an animal’s immune function and its specific cognitive and sensory capacity, from aspects of its ecology. The first half of the course focuses on the genetic foundations of behaviour and the consequences for evolutionary processes such as adaptation and speciation. In the second half of the course, the emphasis is on the adaptive value of cognitive, sensory and immune function and how they contribute to individual variation.
Lent term modules

Memory

Offered by Psychology (Section B) and PDN (Module N8)

Module organiser: Dr J Simons (jss30@cam.ac.uk)

Understanding how information is encoded and retrieved is major research area in behavioural and cognitive neuroscience. Why does one person remember different information to another about a particular event? Why do memories come to mind suddenly and seemingly unbidden? What makes a “good” memory? In this module memory is considered at several different levels of analysis. The module begins with 12 lectures considering memory from the anatomical level to the network, cellular and molecular levels. Topics in these lectures include: amnesia in humans and animals; theories of hippocampal function; computational models of memory; emotional memory and the amygdala; cellular-level consolidation and reconsolidation.

Control of Action

Offered by PDN (Module N3), maximum of 80 students

Module organiser: Dr Steve Edgley (sae1000@cam.ac.uk)

The need to control movement was the impetus behind the genesis of a nervous system. As captured in Sherrington’s statement ‘to move is all mankind can do, whether in whispering a syllable or in felling a forest’, the control of movement is central to our lives. The control of movement is diverse and is as delicate and as subtle as the analysis of sensation. We use the same arm and hand to post a letter, to thread a needle, to pull our bodies up while climbing and to lift a suitcase. Many of the movement-related problems facing us in our everyday lives parallel those of many other species, so can be solved using common principles. A key concept in the control of movement is the organization of the system as a whole to make the outcome successful. The motor systems module looks at the key areas in motor systems control in depth to seek an understanding of the key problems and the ways forward in solving them, covering material extending from the circuits that underlay neural information processing to the performance of the movement itself. The module as a whole covers the principles of motor control from the widespread problems of spinal rhythm generation and control of the motorneuron outputs, to higher level structures involved in learning and modelling behavior. Central to this is how movement are tailored to be effective in the situation in which they occur, using sensory information and learning.

Neural Degeneration and Regeneration

Offered by PDN (Module N5)

Module organiser: Prof. Roger Keynes (rjk10@cam.ac.uk)

Diseases and injuries of the human brain and spinal cord are tragically resistant to treatment. This lecture module investigates the cellular and molecular causes of these conditions, the reasons why regeneration does not take place, and the research now under way to permit regeneration therapies in the future. Serious lifelong disability can be caused by an injury that interrupts axon pathways, most prominently spinal cord
injury. We look at the physiological and clinical aspects, why axon regeneration fails to occur, and how re-wiring can be promoted experimentally. We then look at chronic neurodegenerative diseases, including Alzheimer's, Huntington's and Pick's diseases, examining their origins in genetic and/or biochemical anomalies. Progress has also been made recently in revealing the molecular genetics underlying some forms of intellectual disability, including autistic spectrum diseases, and this topic is covered next. A subsequent course covers the rapidly developing field of neural stem cells, considering both the presence of stem cells able to generate new neurons in some parts of the adult brain, and the potential of stem cells from other sources. We then consider how neural damage occurs due to acute ischaemic injury (stroke), a complex process that has implications for other forms of neural degeneration. Returning to neurodegenerative diseases, we look at the possibility of treatment by cellular grafting or other novel approaches, particularly in Parkinson's and Huntington's diseases. Glial cells are also vital, and are the focus of demyelinating diseases such as multiple sclerosis; so finally, we look at the degeneration and possible regeneration of glial cells.

The lecturers will all discuss research which could lead to new therapies, including development of molecular inhibitors, gene therapy, neural grafting, stem cells, and remyelination. This course is mostly given by researchers from the Clinical School, Vet School, Brain Repair Centre, and Stem Cell Institute.

✓ Central Mechanisms of Reward, Punishment and Emotion
Offered by PDN (Module N6), maximum of 80 students
Module organiser: Prof. Angela Roberts (acr4@cam.ac.uk)

How does the brain process reward and punishment and how does this help us understand emotions and their dysregulation? Wolfram Schultz will discuss the varied functions of reward including learning, approach, positive emotion and economic decision making and how these functions are instantiated in neural circuits including dopamine, the striatum, amygdala, orbitofrontal and lateral prefrontal cortex. Further discussion on positive emotion by Jane Garrison will include the concept of anhedonia and the pathological mechanisms underlying a loss of pleasure. Fabian Grabenhorst will then consider whether this same reward circuitry underlies social behaviour and social cognition. Following on from this, Angela Roberts will describe the limbic and cortical mechanisms by which punishing stimuli impact on our motivations and emotions and inform our decision making. The range of strategies at our disposal for regulating our negative emotions will also be considered and how those strategies are implemented within interacting brain circuits. How, when and why these circuits become dysregulated in psychiatric disorders will be discussed by Hannah Clarke and the importance of understanding body-brain interactions in health and psychiatric disease considered by Golam Khandaker. Finally, Fionnuala Murphy will explore the interplay between cognition and emotion. By the end of the course you should have a better sense of one of the most exciting and active areas of brain research in this decade, that is at the heart of what the brain is all about.

✓ Module N7: Local Circuits and Neural Networks
Offered by PDN (Module N7), maximum of 40 students
Module organiser: Dr David Parker (djp27@cam.ac.uk)
Neural networks form the middle ground in approaches to understanding the nervous system. They assemble the molecular and cellular components needed to process sensory inputs, perform cognitive functions, and pattern motor outputs. Insight into the organisation and function of these networks is essential to understanding how cellular and synaptic properties influence nervous system function and behaviour. Gaining this understanding is currently considered to be the major problem facing neuroscience.

This module will examine the principles of neuronal network function using invertebrate, lower vertebrate, and mammalian model systems. It will outline the requirements that need to be satisfied in order to claim understanding of a network and the extent to which these criteria have been met; outline how cellular and synaptic properties influence network outputs; and illustrate the molecular, anatomical, electrophysiological, imaging, and computational techniques used in network (and other) analyses.

The central role of networks means that this module provides general insight that links to modules that focus on molecular and cellular mechanisms (e.g. how these properties influence higher functions), or to higher-level aspects of sensory, motor, or cognitive functions (e.g. what mechanisms underlie these effects).
The Part II Examination

Students reading Part II Psychology and BBS Psychology take four papers and a research project.

✔️ Written Papers
There will be one written paper per Module. Each paper will draw questions from the lectures within the module and most written papers require candidates to answer three questions on each paper.

✔️ Research Projects
Students taking Part II Psychology, Neuroscience and Behaviour must submit two copies of an independent report on their project. The project report will contribute roughly twice that of each written paper to the total mark.

✔️ BBS Dissertations
Part II BBS candidates will not offer a project. The dissertation is an intrinsic component of their exams and can be offered either within Part II Psychology, Neuroscience and Behaviour or within their minor subject.