Fitzwilliam College Online Winter School Programme 2025

Course brochure

The Fitzwilliam College Online Winter School Programme is organised by Fitzwilliam College, one of the constituent colleges of the University of Cambridge. The programme will let you experience the type of advanced teaching offered at our institution. The same academics who teach our undergraduate students will help you develop your academic skills. The challenging problem-solving and discussion sessions will reflect the style of Cambridge supervisions, which are the core of the excellent teaching offered at the University.

This brochure contains a list of the various short courses that Fitzwilliam College is going to offer in the winter of 2025. Here you can find a detailed description of the contents of each short course, together with a list of prerequisite knowledge and a recommended reading list for the various courses.

I am delighted that Fitzwilliam College can offer you the opportunity to participate in this Winter School Programme. I hope you will enjoy exploring your chosen topic and that partaking in our course will nourish your passion for the subject. I am looking forward to welcoming you soon to the FitzEd Winter School Programme!

Dr Peter Bolgar
Director of the Winter School Programme

Contents:

Microbiology and Pathogen Evolution

(Biology, Genetics, Microbiology, Bioinformatics)

Dr Marta Matuszewska
Research Associate, Department of Medicine, University of Cambridge and
Wellcome Sanger Institute, Wellcome Trust Genome Campus

18th January – 3rd February, 2025

Marta Matuszewska, currently a Research Associate at the University of Cambridge, is an accomplished evolutionary microbiologist specialising in bacterial host adaptation. Holding a PhD in Veterinary Medicine, Marta's research is dedicated to understanding the host range and transmission dynamics of antibiotic-resistant pathogens, with particular focus on *Staphylococcus aureus*. In her current role, she is actively engaged in investigating the biological basis of nasal carriage *by S. aureus* and the role of carriage in disease and evolution and spread of antibiotic resistance. Marta is employing a comprehensive approach that integrates microbiology and genetic epidemiology. Beyond her research, Marta actively contributes to education at the University by leading practical classes in mathematical biology and cell biology. Previously she has supervised undergraduate students in mathematical biology, nurturing the next generation of scientists. Marta also enjoys public science outreach, participating in events such as the Cambridge Science Festival, communicating complex scientific concepts to broad audiences.

Google Scholar: https://scholar.google.com/citations?user=hDJPDIgAAAAJ&hl=en
Cambridge Infectious Diseases Profile: https://www.infectiousdisease.cam.ac.uk/directory/marta-matuszewska
LinkedIn Profile: https://www.linkedin.com/in/marta-matuszewska-b92432131/

Module Structure and Syllabus:

Beijing Time	**18th Jan Saturday 17:00-20:00**	**19th Jan Sunday 17:00-20:00**	**20th Jan Monday 17:00-20:00**	**21st Jan Tuesday 17:00-20:00**	**24th Jan Friday 17:00-20:00**
	Molecular Epidemiology	DNA Structure	Causes and consequences of mutations	Principles of Classification of Micro-organisms	Microbes and Disease
Beijing Time	**25th Jan Saturday 17:00-20:00**	**26th Jan Sunday 17:00-20:00**	**1st Feb Saturday 17:00-20:00**	**2nd Feb Sunday 17:00-20:00**	**3rd Feb Monday 17:00-20:00**
	Bacterial Genomics	Phylogenetics	Phylogenetic Inference	SARS-CoV-2 Pandemic Response	Final Presentations

Molecular Epidemiology: An in-depth introduction to the methodologies and key definitions essential for studying the evolution of pathogens using genomic data. Students will learn the foundational concepts that underpin molecular epidemiology.

DNA Structure: A comprehensive exploration of cell structure, the intricacies of DNA and RNA molecules, and a deep dive into the Central Dogma of biology. This lecture lays the groundwork for understanding genetic information.

Causes and consequences of mutations: A detailed examination of mutations, including their definition, classification into types, an exploration of their consequences on genetic material, and an analysis of the diverse factors contributing to mutagenesis.

Principles of Classification of Micro-organisms: A nuanced discussion on the principles governing the classification of microorganisms, emphasising both phenetic and phylogenetic relationships. Students will gain insights into the taxonomic frameworks that categorise these entities.

Microbes and Disease: An exploration of infectious diseases, covering the spectrum from foodborne and waterborne to airborne diseases. Students will gain a broad understanding of the diverse microbial agents responsible for various health challenges.

Bacterial Genomics: An introduction to the diverse sequencing techniques employed in bacterial genomics. The lecture will guide students through the process of transforming raw sequencing data into a comprehensible genome, providing essential insights into genomic analyses.

Phylogenetics: A deep dive into phylogenetic principles, including real-world examples of phylogenies, discussions on phylogenetic tree rooting and topology, applications in diverse contexts, and a critical examination of potential pitfalls in phylogenetic analyses.

Phylogenetic Inference: Building upon the previous lecture, students will learn the practical aspects of phylogenetic inference. This includes creating alignments, understanding distance matrices, selecting appropriate substitution models, and exploring various approaches to construct phylogenetic trees, such as Neighbour-Joining, Likelihood-based methods, and Bayesian phylogenetic inference.

SARS-CoV-2 Pandemic Response: A special guest lecture by Dr. Christopher Ruis, offering unique insights into his work during the SARS-CoV-2 pandemic response. Students will gain a first-hand understanding of applying mutational spectra and phylogenetics to decipher pathogen transmission patterns.

Final Presentations: The culmination of the course, where students present their comprehensive understanding of molecular epidemiology and pathogen evolution. Each presentation will showcase the application of acquired knowledge and skills, providing a tangible demonstration of the course's impact on the students' analytical capabilities and scientific acumen.

List of prerequisite knowledge:

There is no required prerequisite knowledge for this course. Students are encouraged to gain some basic computational skills in Linux and coding if they have an opportunity, but this is not necessary for joining the course. A broad familiarity with the items on the list above will greatly enhance your understanding and enjoyment of the classes and good preparation by all students will contribute significantly to the success of the course.

Recommended reading list (optional):

Brown, T. A. (2002). *Mutation, Repair and Recombination*.
https://www.ncbi.nlm.nih.gov/books/NBK21114/

Costa dos Santos, G., Renovato-Martins, M., & de Brito, N. M. (2021). The remodel of the "central dogma": a metabolomics interaction perspective. *Metabolomics: Official Journal of the Metabolomic Society*, *17*(5). https://doi.org/10.1007/S11306-021-01800-8

Crick, F. (1970). Central Dogma of Molecular Biology. *Nature 1970 227:5258*, *227*(5258), 561–563. https://doi.org/10.1038/227561a0

Foxman, B., & Riley, L. (2001). Molecular Epidemiology: Focus on Infection. *American Journal of Epidemiology*, *153*(12), 1135–1141. https://doi.org/10.1093/AJE/153.12.1135

Hall A. What is molecular epidemiology? (Editorial). *Trop Med Int Health* 1996;1:407–8.

Lakhundi, S., & Zhang, K. (2018). Methicillin-Resistant *Staphylococcus aureus*: Molecular Characterization, Evolution, and Epidemiology. *Clinical Microbiology Reviews*, *31*(4). https://doi.org/10.1128/CMR.00020-18

MacPhee, D. G., & Ambrose, M. (1996). Spontaneous mutations in bacteria: chance or necessity? *Genetica*, *97*(1), 87–101. https://doi.org/10.1007/BF00132585

Pitt, T. L., & Barer, M. R. (2012). Classification, identification and typing of micro-organisms. *Medical Microbiology*, 24. https://doi.org/10.1016/B978-0-7020-4089-4.00018-4

Tompkins LS. Molecular epidemiology: development and application of molecular methods to solve infectious disease mysteries. In: Miller VL, Kaper JB, Portnoy DA, et al, eds. Molecular genetics of bacterial pathogenesis: a tribute to Stanley Falkow. Part 1. Retrospective look at early advances. Washington, DC: American Society for Microbiology, 1994:63–73

Office hours: 8pm – 9pm Tuesday 21st Jan, 8pm – 9pm Sunday 2nd Feb.

Special Relativity and Quantum Mechanics
(Physics)

Dr Joao Rodrigues
Director of Studies, St Catharine's College, University of Cambridge
Bye-Fellow, Wolfson College, University of Cambridge

18th January – 3rd February, 2025

After many years working in Quantum Field Theory and Particle Physics, specifically in the parton structure of the nucleons, I changed my field of research to the climate of the polar regions. In the Polar Oceans Physics Group in Cambridge, I studied how the Arctic sea ice cover has changed in recent decades as a consequence of global warming. I examined sea ice thickness data collected by submarines and satellites and attempted to quantify the dramatic thinning of the Arctic Sea ice. At present, I teach several Physics and Mathematics courses for first-, second- and third-year students in the Natural Sciences and the Mathematical Tripos of the University of Cambridge.

College Profile: https://www.wolfson.cam.ac.uk/people/dr-joao-rodrigues

Module Structure and Syllabus:

Beijing Time	**18th Jan Saturday 17:00-20:00**	**19th Jan Sunday 17:00-20:00**	**20th Jan Monday 16:00-19:00**	**21st Jan Tuesday 16:00-19:00**	**24th Jan Friday 16:00-19:00**
	The Lorentz Transformation	Relativistic Kinematics	Relativistic Dynamics	Relativistic Optics	Appearance of rapidly moving objects
Beijing Time	**25th Jan Saturday 17:00-20:00**	**26th Jan Sunday 17:00-20:00**	**1st Feb Saturday 17:00-20:00**	**2nd Feb Sunday 17:00-20:00**	**3rd Feb Monday 16:00-19:00**
	The historical development of QM	The postulates of QM and simple applications	The EPR paradox and the Bohr-Einstein debate	Bell's Inequality	Final Presentations

The Lorentz Transformation: We highlight the successes and difficulties of the pre-relativistic physics. The latter was very effective in predicting, for instance, the motion of the planets, but Einstein noticed what appeared to be an inconsistency between Newton's dynamics and Maxwell's electromagnetism. This led him to propose a new physical theory and a new transformation law for the coordinates of the same event in two different reference frames. Different observers may assign different times to the same event, a curious feature of what became known as the Lorentz transformation.

Relativistic Kinematics: The fact that time flows at different rates in different systems of reference has interesting consequences. We shall follow a fast-moving interstellar spaceship and compare the magnitudes of time intervals, distances and velocities measured by those in the ship with the corresponding measurements made by observers at rest. In this context, we shall examine in detail the well-known Twin Paradox.

Relativistic Dynamics: We introduce the notions of relativistic momentum and energy and study some examples of the conversion of mass into energy and vice-versa. We derive the famous formula $E=mc^2$ and explore its implications in some physical systems.

Relativistic Optics: The Doppler effect and the aberration of light were known phenomena in non-relativistic physics. We shall assess how Relativity modifies the classic formulas and explore some of the consequences of these changes.

Appearance of rapidly moving objects: When taking a photograph of a moving object, all rays generated at its boundaries arrive simultaneously at the camera. If the object has a non-negligible size, light rays must then leave its surface at different times. In most instances this causes a significant distortion on the appearance of objects that move at speeds close to the speed of light. However, perhaps surprisingly, some objects keep their shape in the photographs.

The historical development of Quantum Mechanics: The first quarter of the twentieth century is often regarded as one of the most productive periods in the history of science. We shall study the ideas of Planck, de Broglie, Heisenberg, Schrodinger, and others which culminated in 1925-1926 with the formulation of the Quantum Theory.

The postulates of Quantum Mechanics and simple applications: We introduce the notion of wave function, quantised energy levels and solve Schrodinger's equation for simple systems. We discuss how the equation can be applied to more complicated systems such as the hydrogen atom.

The EPR paradox and the Bohr-Einstein debate: The new ideas were not accepted without reluctance by some, among them Einstein. In 1935, together with Podolsky and Rosen, he wrote an article in which an apparent paradox suggested that the formulation of Quantum Mechanics was incomplete. We shall discuss their reasoning and the more modern version of the paradox due to Bohm.

Bell's Inequality: Almost 30 years after the EPR argument was formulated, Bell wrote what has been described as one of the most important scientific works of the 20th century, in which it was shown that Quantum Mechanics could not be completed with the so-called hidden variables. We shall have a good discussion of Bell's theorem and some of its variants, namely due to d'Espagnat.

List of prerequisite knowledge:

Newtonian dynamics:
- Newton's Laws
- Notions of force, mass, momentum, energy and work

Optics:
- The laws of reflection and refraction
- Notion of frequency, period, wavelength

Mathematics:
- Elementary techniques of differentiation and integration
- Techniques for solving simple first and second order differential equations (desired but not strictly necessary)

Recommended reading list (optional):

Halliday and Resnick, *Fundamentals of Physics* (Relativity and Quantum Mechanics chapters only);
A Einstein, *The Principle of Relativity*;
R Feynman, *The Feynman Lectures on Physics*, Quantum Mechanics (Chapter 1 only);

Office hours: 7pm – 8pm Tuesday 21st Jan, 8pm – 9pm Sunday 2nd Feb.

Mathematics for the Natural Sciences
(Mathematics)

Mrs Serena Povia
College Teaching Associate at St John's College
Supervisor at Magdalene and Jesus
Involved in Cambridge Admissions for the past 6 years in several colleges
STEMSMART Supervisor

18th January – 3rd February, 2025

I specialise in teaching Mathematics and Physics at the University level. I have been a supervisor in physics and mathematics for the Natural Sciences course for about ten years. My current teaching commitments are the Physics and Mathematics courses for the first year and the second year of the respective Tripos. I previously taught third-year courses too.

College Profile: https://www.joh.cam.ac.uk/fellow-profile/410

Module Structure and Syllabus:

Beijing Time	**18th Jan Saturday 17:00-20:00**	**19th Jan Sunday 17:00-20:00**	**20th Jan Monday 17:00-20:00**	**21st Jan Tuesday 17:00-20:00**	**24th Jan Friday 17:00-20:00**
	Differentiation 1	Integration 1 and differential equations 1	Exponentials and Logarithms	Trigonometry and Hyperbolics	Differentiation 2
Beijing Time	**25th Jan Saturday 17:00-20:00**	**26th Jan Sunday 17:00-20:00**	**1st Feb Saturday 17:00-20:00**	**2nd Feb Sunday 17:00-20:00**	**3rd Feb Monday 17:00-20:00**
	Integration 2 and differential equations 2	Differential Equations 3	Complex Numbers	Differential Equations 4	Final Presentations

Differentiation 1: We introduce differentiation, give some simple example; we introduce sketching simple functions.

Integration 1 and differential equations 1: We introduce integration of simple functions and the construction of differential equations using simple physical examples where possible.

Exponential and Logarithms: We introduce, learn to sketch, and learn to differentiate exponentials and logarithmic functions.

Trigonometry and Hyperbolics: We introduce, learn to sketch, and learn to differentiate several useful trigonometric functions (including inverses and hyperbolics)

Differentiation 2: We introduce product, quotient, and chain rule for differentiation; we introduce implicit differentiation.

Integration 2 and differential equations 2: We introduce integration by substitution and by parts; we introduce the integration of differential equations.

Differential equations 3: We proceed in learning how to work with differential equations, strongly tying it back to physics wherever possible.

Complex Numbers: We need the formalism of complex numbers to solve harder physics problems; we introduce and use the cartesian and polar forms.

Differential equations 4: Simple harmonic oscillator physics requires a different style of solution that will use Complex Numbers.

List of prerequisite knowledge:
GCSE, IGCSE or equivalent qualification. No calculus required as we will cover everything from first principles.

Office hours: 8pm - 9pm Monday 20th Jan, 8pm - 9pm Sunday 2nd Feb.

Psychology and Neuroscience

Dr Alexandra Krugliak
Research Associate at MRC Cognition and Brain Sciences Unit, University of Cambridge
Former supervisor, Trinity College, University of Cambridge

18th January – 3rd February, 2025

I studied Psychology and Cognitive Neuroscience at The University of Maastricht (The Netherlands), before obtaining a PhD from the University of Birmingham (United Kingdom). Currently I am a Research Associate at the MRC Cognition and Brain Sciences Unit at the University of Cambridge. My main research interest is how the human brain represents the world around us based on perception, memory and learning, and how these processes change during healthy and pathological ageing. I combine neuro-imaging techniques such as Electroencephalography (EEG), Magnetoencephalography (MEG), and functional Magnetic Resonance Imaging (fMRI) with cutting-edge computational approaches to study neural representations of visual and auditory perception both in healthy participants and in patients with Alzheimer's disease.

Departmental Profile: https://ftd.neurology.cam.ac.uk/staff/dr-alexandra-krugliak

Module Structure and Syllabus:

Beijing Time	**18th Jan Saturday 17:00-20:00**	**19th Jan Sunday 17:00-20:00**	**20th Jan Monday 17:00-20:00**	**21st Jan Tuesday 17:00-20:00**	**24th Jan Friday 17:00-20:00**
	Intro Psychology	Methods	Experimental Design	Cognitive Psychology	Cognitive Neuroscience
Beijing Time	**25th Jan Saturday 17:00-20:00**	**26th Jan Sunday 17:00-20:00**	**1st Feb Saturday 17:00-20:00**	**2nd Feb Sunday 17:00-20:00**	**3rd Feb Monday 17:00-20:00**
	Visual Perception	Memory	Attention	Psychopathology	Final Presentations

Intro Psychology: Introduction to the fundamentals of Psychology.

Methods: The scientific method and how it applies to Psychology and Neuroscience.

Experimental Design: Overview of the methods used in research and applied Psychology.

Cognitive Psychology: Theoretical frameworks of how humans think and process information.

Cognitive Neuroscience: Studying the brain with neuro-imaging methods and computational approaches, and what it reveals about how the mind works.

Visual Perception: How visual information is perceived and processed in the brain: organisation of the visual systems in humans and animals, visual illusions, effects of lesions on visual experience.

Memory: Mechanisms underlying the formation and retrieval of memories: short- versus long-term memory, memory formation, remembering, patient studies.

Attention: Attention guides how we perceive the world: theories of attention, selective attention, active perception.

Psychopathology: What happens when the brain and behaviour work atypically: the diagnostic process and treatments for mental disorders.

List of prerequisite knowledge:
Basic knowledge of brain anatomy and function.

Office hours: 8pm- 9pm Monday 20th Jan, 8pm- 9pm Sunday 2nd Feb.

Sustainable Vehicles
(Engineering)

Dr Andrea Giusti
Bye-Fellow, Fitzwilliam College, University of Cambridge
Senior Lecturer in Thermofluids, Department of Mechanical Engineering, Imperial College London

18th January – 3rd February, 2025

Andrea is a Senior Lecturer in Thermofluids at Imperial College London, Department of Mechanical Engineering and Bye-Fellow of Fitzwilliam College, Cambridge. He studied Mechanical and Energy Engineering in Florence (Italy). He obtained a PhD in 2014 at the University of Florence, working on a project for the development of clean engines for airplanes. Following his PhD, Andrea joined the Engineering Department at the University of Cambridge as a Rolls-Royce Research Associate. He was appointed Lecturer by Imperial College in October 2018. In addition to the academic role at Imperial College, Andrea supervises undergraduate students at Fitzwilliam College. He is also Editor-in-Chief of the International Journal of Spray and Combustion Dynamics.

College Profile: https://www.fitz.cam.ac.uk/person/dr-andrea-giusti
Departmental Profile: https://www.imperial.ac.uk/people/a.giusti

The objective of the module is to learn the fundamentals to develop an innovative conceptual design of a sustainable vehicle. The set of problems designed to support the learning will lead the student to a proposal of an innovative vehicle and a critical evaluation of its feasibility.

Module Structure and Syllabus:

Beijing Time	**18th Jan Saturday 15:00-18:00**	**19th Jan Sunday 15:00-18:00**	**20th Jan Monday 15:00-18:00**	**21st Jan Tuesday 15:00-18:00**	**24th Jan Friday 15:00-18:00**
	Engineering and Innovation	Sustainability and Life cycle assessment	Vehicle dynamics	Aerodynamic forces	Internal combustion engines
Beijing Time	**25th Jan Saturday 15:00-18:00**	**26th Jan Sunday 15:00-18:00**	**1st Feb Saturday 15:00-18:00**	**2nd Feb Sunday 15:00-18:00**	**3rd Feb Monday 15:00-18:00**
	Fuels and emissions	Electrification of cars	Future vehicle concepts	Ethics and intellectual property	Final Presentations

1. **Engineering and Innovation**
    a. Duration: 3 hours (2 hours of lecture; 1 hour of problems/discussion)
    b. Syllabus: ideal engineering system, S-shaped curve, transition to the super-system, micro-scale interactions, systematic innovation, nature-inspired innovation, examples.

c. In-class problems: finding bio-inspired solutions for the improvement of the performance of a car.
d. Assignment: definition of ideal car and identification of barriers to innovation.

2. **Sustainability and Life cycle assessment**
    a. Duration: 3 hours (2 hours of lecture; 1 hour of problems/discussion)
    b. Syllabus: the lifecycle of a component/system, climate crisis, the concept of sustainability, multi-criteria decision analysis, the various phases of the life cycle assessment, example.
    c. In-class problems: life cycle assessment of a car.
    d. Assignment: multi-criteria decision analysis.

3. **Vehicle Dynamics**
    a. Duration: 3 hours (2 hours of lecture; 1 hour of problems/discussion)
    b. Syllabus: forces on vehicles, wheels and forces exchanged on the ground, power requirements.
    c. In-class problems: identification of engine power requirements for a given performance.
    d. Assignment: computation of power required for different slope angles.

4. **Aerodynamic forces**
    a. Duration: 3 hours (2 hours of lecture; 1 hour of problems/discussion)
    b. Syllabus: fundamentals of friction and drag, flow separation, streamlining, wing profiles, lift and downforce.
    c. In-class problems: computations of reduction of drag (case study).
    d. Assignment: sketch of an aerodynamic vehicle.

5. **Internal Combustion Engines**
    a. Duration: 3 hours (2 hours of lecture; 1 hour of problems/discussion)
    b. Syllabus: overview of internal engines, fundamentals of thermodynamics, torque, power, efficiency.
    c. In-class problems: coupling between an engine and a car; introduction to gear box.

6. **Fuels and emissions**
    a. Duration: 3 hours (2 hours of lecture; 1 hours of problems/discussion)
    b. Syllabus: classification of fuels, emissions from engines, biofuels, hydrogen
    c. In-class problems: quantification of carbon dioxide emitted by hydrocarbon combustion.

7. **Electrification of cars**
    a. Duration: 3 hours (2.5 hours of lecture; 0.5 hours of problems/discussion)
    b. Syllabus: hybrid cars, fully electric cars, fundamentals of fuel cells and batteries, energy, and power density.
    c. In-class problems: coupling between a car and an electrical powertrain.

8. **Future vehicle concepts**
    a. Duration: 3 hours (1.5 hours of lecture; 1.5 hour of problems/discussion)
    b. Syllabus: autonomous vehicles, urban air mobility, electric aircraft.

   c. In-class problems: conceptual design of a sustainable vehicle.

9. **Ethics and Intellectual property**
   a. Duration: 3 hours (2 hours of lecture; 1 hour of problems/discussion)
   b. Syllabus: patents, copyright, registered design, trademark, confidentiality, professional ethics, engineering ethics.
   c. In-class problems: patent search, patent reading.

List of prerequisite knowledge:
Fundamental concepts of mechanics (Newton's second law, friction force, velocity, acceleration along a straight line); the concept of energy and power; the concept of pressure. Optional: chemical reactions (reading reactants and products; balancing the reaction).

Recommended reading list (optional):
Any book on physics for high school.

Office hours: 6pm – 7pm Tuesday 21st Jan, 6pm – 7pm Sunday 2nd Feb.

Elements of Mathematical Economics

(Mathematics and Economics)

Dr Vasileios Kotsidis

College Assistant Professor, Gonville and Caius College, University of Cambridge

18th January – 3rd February, 2025

Vasileios Kotsidis uses tools from traditional and evolutionary game theory to analyse social interactions that (potentially) involve strategic motives. His research focuses on the scope and limitations of models based on methodological individualism in interpreting individual behaviour (human or otherwise) as it is manifested in social settings. It spans along three main directions: how individuals think, what they are motivated by, and what the researcher can infer. He obtained his PhD in Economics at the University of Nottingham. His doctorate explored some theoretical aspects of social (strategic) behaviour and investigated its empirical manifestations. He also enjoys practicing karate, studying the philosophy of mathematics, and reading fantasy literature.

Module Structure and Syllabus:

Beijing Time	**18th Jan Saturday 17:00-20:00**	**19th Jan Sunday 17:00-20:00**	**20th Jan Monday 17:00-20:00**	**21st Jan Tuesday 17:00-20:00**	**24th Jan Friday 17:00-20:00**
	Elements of Mathematics I	Elements of Mathematics II	Elements of Statistics I	Elements of Statistics II	Rational Choice Theory I
Beijing Time	**25th Jan Saturday 17:00-20:00**	**26th Jan Sunday 17:00-20:00**	**1st Feb Saturday 17:00-20:00**	**2nd Feb Sunday 17:00-20:00**	**3rd Feb Monday 17:00-20:00**
	Rational Choice Theory II	Stochastic Dominance	Dynamic Choice	Information	Final Presentations

Elements of Mathematics I and II: These lectures introduce students to fundamental concepts of mathematics that have useful applications in economics.

Elements of Statistics I and II: These lectures provide the statistical foundations necessary for the analysis of economic processes and relations.

Rational Choice Theory I and II: These lectures introduce a formal theory of choice and examine some applications in economic transactions.

Stochastic Dominance: This lecture discusses conditions under which certain options outperform others, with reference to some key statistical properties.

Dynamic Choice: This lecture discusses formal choice in a temporal setting and examines financial decisions with varying time-horizons.

Information: This lecture investigates the ways in which rational agents can incorporate newly acquired pieces of information into their decision-making process.

List of prerequisite knowledge:
Basic differentiation is necessary and basic integration is desirable.

Office hours: 8pm – 9pm Tuesday 21st Jan, 8pm – 9pm Sunday 2nd Feb.

Supramolecular Chemistry: Designing and Building Smart Materials

(Chemistry)

Dr Giulia Iadevaia

Teaching Bye-Fellow at Churchill College, University of Cambridge

Chemistry Laboratory Operations Manager, The Francis Crick Institute, London

18th January – 8th February, 2025

Dr Giulia Iadevaia gained her MSc in Chemistry from the Sapienza University of Rome in 2010 after doing her final year project on anion recognition. She got her PhD from the University of Sheffield in 2014 working on cooperative hydrogen bonded systems. She then worked for two years as a postdoctoral researcher in the group of Professor Christopher Hunter FRS, at the Department of Chemistry at the University of Cambridge. She was then appointed as Research Laboratory Manager in the same group and she held the position for six years. Her research focused on the study of supramolecular systems, more specifically on the synthesis and analysis of abiotic analogues of information molecules like DNA. Giulia currently works at the Francis Crick Institute in London, where she is responsible for the science operations and the smooth running of the Chemistry Laboratories.

Over the past 8 years, Giulia has taught a wide range of courses in Chemistry at the University of Cambridge, from all years of the undergraduate curriculum. Since 2021 she has been a Teaching By-Fellow at Churchill College. She is passionate about organic chemistry, in particular about physical organic chemistry and supramolecular chemistry.

College Profile: https://www.chu.cam.ac.uk/fellows/giulia-iadevaia/

Module Structure and Syllabus:

Beijing Time	18th Jan Saturday 14:00-17:00	19th Jan Sunday 14:00-17:00	20th Jan Monday 14:00-17:00	21st Jan Tuesday 14:00-17:00	23rd Jan Thursday 14:00-17:00
	Introduction to non-covalent interactions I	Introduction to non-covalent interactions II	Thermodynamics of non-covalent interactions	Analytical techniques and solvent effects	Introduction to molecular recognition
Beijing Time	**24th Jan Friday 14:00-17:00**	**25th Jan Saturday 14:00-17:00**	**26th Jan Sunday 14:00-17:00**	**1st Feb Saturday 14:00-17:00**	**8th Feb Saturday 14:00-17:00**
	Supramolecular systems I	Supramolecular systems II	Self-Assembly and Template synthesis	Molecular Machines	Final Presentations

Introduction to Non-covalent Interactions I and II

Explore various non-covalent interactions used by supramolecular chemists to link molecules, including electrostatics, hydrogen bonding, π-interactions, and van der Waals forces.

Thermodynamics of Non-covalent Interactions
Discuss parameters like enthalpy, entropy, and free energy to understand how these forces influence molecular stability and binding.

Analytical Techniques and Solvent Effects
Explore analytical techniques used in supramolecular systems, including NMR, UV, and fluorescence spectroscopy, to study structure and binding interactions. Discuss solvent effects that influence non-covalent interactions by altering stability, solubility, and molecular behaviour.

Introduction to Molecular Recognition
Explore the field of supramolecular chemistry through an introduction to key design principles, including the chelate, macrocyclic, and cryptate effects, as well as cooperativity and solvation effects.

Supramolecular Systems I and II
Discuss host-guest recognition in supramolecular chemistry, including the design principles behind cation, anion, and neutral guest recognition. Learn about the significance of this field, exemplified by the Nobel Prize in Chemistry awarded in 1987. Discuss various techniques used to synthesize and study supramolecular systems such as molecular containers and cages.

Self-Assembly and Template Synthesis
Discuss the process of self-assembly, where large supramolecular structures are formed/organized through non-covalent interactions, with a focus on examples found in nature such as DNA. Additionally, explore template synthesis, where a molecular scaffold guides the formation of specific supramolecular architectures.

Molecular Machines
Explore molecular machines in supramolecular chemistry—nanoscale devices that perform specific tasks through controlled molecular motion, driven by external stimuli like light, heat, or chemical reactions.

Prerequisite knowledge:
Basic organic chemistry (reactions that would normally be covered at secondary school-level organic chemistry, familiarity with the meaning of curly arrows desirable but not essential)

Office hours: 5.30pm – 6.30pm Wed 22nd Jan and 5.30pm – 6.30pm Saturday 1st Feb

Computer Science: Artificial Intelligence

Dr John Fawcett
Churchill College, University of Cambridge

18th January – 3rd February, 2025

Since completing his PhD, John Fawcett has been working in industry alongside lecturing, tutoring, supervising and directing studies in Computer Science at Cambridge. Over more than 15 years, John has seen around 500 students through to graduation. John has delivered courses in summer schools over 10 years and is active in undergraduate admissions, including being Subject Convenor. John served as University Senior Proctor in academical year 2021/22 after being Praelector for 6 years at Churchill.

College Profile: https://www.chu.cam.ac.uk/fellows/dr-john-fawcett/

Module Structure and Syllabus:

Beijing Time	**18th Jan Saturday 14:00-17:00**	**19th Jan Sunday 14:00-17:00**	**20th Jan Monday 14:00-17:00**	**21st Jan Tuesday 14:00-17:00**	**24th Jan Friday 14:00-17:00**
	Classic search problems in artificial intelligence	Scaling to real world search problems	Interactive decision making	Prolog	Understanding Knowledge
Beijing Time	**25th Jan Saturday 14:00-17:00**	**26th Jan Sunday 14:00-17:00**	**1st Feb Saturday 14:00-17:00**	**2nd Feb Sunday 14:00-17:00**	**3rd Feb Monday 14:00-17:00**
	Automating a warehouse	Training a Neural Network	Bayesian Inference in the real world	Limits of machine learning	Presentations

Each of the following will use lecture time to introduce and explain new concepts, followed each day with practical programming exercises: learning-by-doing through scaffolded exercises giving room for learners to solve problems in their own ways.

Classic search problems in artificial intelligence: many problems have a solution; many games have an optimal strategy. But how do we find them? What data structures and algorithms can we use?

Scaling to real world search problems: redesigning our algorithms to better match the limits of modern hardware and to handle different user requirements.

Interactive decision making: how can we handle problems that change while we are implementing our solution? Dynamic, or interactive, search problems pose interesting new challenges!

Prolog: we will learn a new programming language that can help us to implement our AI algorithms!

Understanding knowledge: each of us has an intuitive understanding of common sense and knowledge, but how can we represent that in a computer, and what format(s) make it usable?

Automating a warehouse: pulling all the pieces together, let's design the algorithms that a robot needs to pack items into boxes.

Training a neural network: generalising our approach, can we design systems that can design themselves?

Bayesian inference in the real world: guest lecture looking at the opportunities and economics of machine learning in the real world.

Limits of machine learning: understanding the practicalities of contemporary machine learning solutions and the implications for their reliability, trust worthiness, hallucinations, etc.

List of prerequisite knowledge:
No computer science knowledge is assumed but programming experience is always useful.

Office hours: 5.30 pm – 6.30 pm Monday 20th Jan, 8pm – 9pm Sunday 2nd Feb