MD1A4-45 Integrated Science Organelles and Cells

24/25

Department
Warwick Medical School
Level
Undergraduate Level 1
Module leader
Masanori Mishima
Credit value
45
Module duration
10 weeks
Assessment
70% coursework, 30% exam
Study location
University of Warwick main campus, Coventry

Description

Introductory description

The module aims to equip students with the conceptual, theoretical and computational skills required for the analysis and engineering of prokaryotic and eukaryotic organelles and cells.

Module web page

Module aims

Students will learn to solve scientific problems in this area by integrating concepts and approaches from different scientific disciplines, including biology, physics, chemistry, mathematics and computing.

Outline syllabus

This is an indicative module outline only to give an indication of the sort of topics that may be covered. Actual sessions held may differ.

Block 6 Mathematical Skills

Lecture 1 - Basic Statistics
Mean, median, mode, histogram, R, variance, standard deviation, standard error, confidence interval.
Lecture 2 - Trigonometry
Pi, radian, sin, cos, tan, sum & difference identities, sum to product identities
Lecture 3 - Calculus
Integration by substitution, integration by parts
Lecture 4 - ODE
Overview, general solution, particular solution
Lecture 5 - Linear Algebra
Vector, dot product.
Lecture 6 - Statistics
Probability, probability mass finction, probability density function
Lecture 7 & 8 - Coach writeup
Dry Lab 1 - Formula handling
Dry Lab 2 - Calculus
Dry Lab 3 - Complex numbers, waves
Dry Lab 4 - ODE
Dry Lab 5 - Linear algebra
Dry Lab 6 - Statistics
In-class exam

B7 BioElectricity
How does life harness electrical forces?
We will learn how life harnesses electricity to communicate and compute information. We will discover how cells use energy to create electro-chemical gradients and express proteins that behave as selective pores in the plasma membrane to control where, when and how certain ions pass into and out of the cell. Using both experimentation and computer models we will delve deeper into how the emergent behaviour of these electrically excitable cells leads to the ability to control the heartbeat, kick a football, or think about why we are here!

Lec1 | Electrostatics & Debye screening: Nernst equation applied to intra-molecular interactions. The superposition principle; ionic bonds, hydrogen bonds, London dispersion forces can all be explained by Coulombic interactions; dipoles and dielectric effect; Bjerrum length calculation

- Discuss the consequences of the Nernst equation
- Discuss the extent to which life is an electrical phenomenon
  Lec2 | Introduction to neuroscience Membrane potentials, chemical synapses, gap junctions, calcium compartments
- Describe the structure and electrical signalling mechanisms of gap-junctions
  Lec4 | Hodgkin and Huxley: Hodgkin-Huxley model in neuroscience, solutions by simulations
- Simulate neuronal action potentials using Mathematica
  Lec5 | Optogenetics, behavioural feedback loops: Using light to control neural activity and probe the function of nervous systems
- Discuss, with examples, the utility of optogenetic manipulations in biology
  Lec6 | Control engineering: Resistors, capacitors, transistors, logic circuits
- Interpret and design logic circuits
  Lec7 | Ion Channels: structure and biological roles of ion channels 7 pumps

- Discuss and exemplify the classes, structures and biological roles of ion channels
  Lec8 | Neurons and neural networks: growth, insulation, synapsis of neurons
- Describe how neurons grow and synapse

B8 Synthetic biology
How can we use chemistry to make biological probes?
You will learn about protein synthesis and the key chemical reaction in this process, namely the formation of a peptide (amide) bond. But, you will use synthetic biology to design a new protein with a new amino-acid, a new codon, and a new translation apparatus. None of which exists in nature! Using the synthetic biology approach, you will learn about how normal protein synthesis is accomplished.

Lec1 | Reaction kinetics redux: the logic of chemistry

- Assemble rate equations for chemical reactions
  Lec2 | Molecular Modelling: Chemdraw. Pymol.
- Harness open source software to display and examine molecular structures
  Lec3 | Synthetic chemistry: Screening for activity
- Describe strategies for building, arraying and testing compound libraries
  Lec4 | Linkers: tagging, affinity techniques , crosslinking agents
- Exemplify the experimental uses of reversible and irreversible molecular tagging
  Lec5 | Solvation: phases, phase transitions
- Explain solvation mechanisms and their role in determining reactivity
  Lec6 | Ligand binding mechanisms
- Describe how metals bind and contribute to protein function
  Lec7 | Inhibitors and activators: Pharmacology
- Exemplify small molecule inhibition and activation of enzymes
  Lec8 | Genetic code expansion
- Discuss technological approaches to genetic code expansion

Labs: Over the 2 weeks of the block (6 lab sessions) students will use generic code expansion to engineer a protein incorporating a specific unnatural amino acid in a specific residue postion, express,

B9 Light

Lec 1 - Ray optics 1
Overview view of light microscopy, Speed of light. Refraction, Refractive index, Focal points and principal planes, Lensmaker's equation.
Lec 2 - Ray optics 2
Image formation by a lens, Lateral and axial magnifications, System of lenses, Infinity optics
Lec 3 - Wave optics 1
Maths for rotation, oscillation and wave, Light as electromagnetic wave, Dispersion, Polarisation
Lec 4 - Wave optics 2
Complex exponentials, Interference/diffraction
Lec 5 - Light-matter interaction
Light as a quantum phenomenon, Fluorescence, LED, Image sensor
Lec 6 - Imaging by a microscope

Numerical aperture, Optical resolution, Fourier transform, Band-pass filters.

Lab 1 - Lenses, prisms, measurement of refractive index
Lab 2 - Collimation, diffraction by optical disks, Fraunhofer diffraction
Lab 3 - Measurement of PSF
Lab 4 - Photobleaching of GFP
Lab 5- Stroboscopy 1 High-speed control of LED flashing
Lab 6 -Stroboscopy 2 Measurement of the frequency of vibration by a smartphone
Lab 7 - Write paper
Lab 8 - Write paper

B10 - Pathogens and Parasites| Sam Dean
How have parasites evolved to invade our bodies?

Lec1 | Flagellar-driven motility

- Overview of eukaryotic flagella: their structure, how they are assembled and their varied functions
  Lec2 | African Sleeping Sickness and trypanosomes
- Overview of Trypanosoma brucei: their lifecycle and how, despite being continuously exposed to host antibodies, they thrive in the host blood
  Lec3 | Intracellular parasites
- Overview of Leishmania and Trypanosoma cruzi, hugely successful kinetoplastid parasites that actually invade the cells that are supposed to kill them
  Lec4 | Gliding motility in apicomplexans
- How parasites move WITHOUT a flagellum and how is this machinery used to move through host cells and invade them
  Lec5 | Plasmodium and Malaria
  Plasmodium parasites that cause malaria, the big killer. How they resist the drugs that are supposed to kill them, and how humans have evolved to combat them
  Lec6 | Toxoplasma and toxoplasmosis
- Toxoplasma: “Why cats?” and how the parasite modifies the host behaviour (or not…)
  Lec7 | Co-evolution of parasites and the immune system
- How the evolution of pathogens and parasites has also driven the devlopment of our immune system and other host defences

Learning outcomes

By the end of the module, students should be able to:

- Demonstrate the ability to apply creative analytical thinking in order to frame and answer scientific questions, especially about the structures, functions and mechanisms of cells and cellular organelles.
- Demonstrate a grasp of physical law as it applies to the structures and behaviours of living cells and their organelles, especially nuclei.
- Use mathematical approaches to solve problems relating to the structure and behaviours of living cells and their organelles.
- Describe and interpret quantitatively the mechanisms by which life harnesses electrical forces

- Access and use the scientific literature effectively
- Demonstrate the writing skills required to report experimental results in the format of a scientific paper, including the ability to write an abstract, to write a short critical review of the relevant literature, present results in an appropriate format and detail with appropriate statistics, discuss the results and frame a clear conclusion.
- Harness computation to analyse scientific data
- Demonstrate the hands-on practical skills required to perform experimental tests of tractable scientific questions, especially about the structure and dynamics of cells and their organelles.
- Describe and interpret quantitatively how synthetic biology can be used to interrogate the mechanisms of life.
- Demonstrate a grasp of the properties of light and the principles of optical image formation
- Describe and discuss how pathogens and parasites have evolved to invade their hosts.
- Demonstrate the ability to accurately record experimental procedures and results in appropriate detail.
- Operate safely within a laboratory environment.

Indicative reading list

Biophysics and Physics
Physical Biology of the Cell Phillips et al Garland Science 2013
Molecular cell biology
Molecular Biology of the Cell, 2014. Bruce Alberts et al ISBN: 9780815344322.
Biochemistry
Biochemistry (8th Edition) 2015. Jeremy Berg et al. ISBN-10: 1-4641-2610-0.
Lewin's Genes XI, 2013. Krebs, Goldstein, Kilpatrick. ISBN: 128402721X
Chemistry
Principles of Modern Chemistry, 8th Edition 2016
Oxtoby, Gillis, Butler ISBN: 9781305079113
Mathematics
Street-fighting mathematics 2010. Mahajan. ISBN : 978-0-262-51429-3
Measurements and their uncertainties 2010. Hughes & Hase. ISBN: 978-0-19-956632-7
Statistics at the bench 2010. Bremer & Doerge. ISBN: 978-0-87969-857-7
Basic mathematics for chemists Peter Tebbutt (2nd edition) 1998. Wiley ISBN: 978-0-471-97284-6
Computing
Physical models of living systems Philip Nelson 2015 WH Freeman ISBN: 978-1-4641-4029-7
Programming in Python 3: A Complete Introduction to the Python Language (Developer's Library) Mark Summerfield ISBN: 978-0-321-68056-3
Math notes on Trigonometry, Basic Calculus, Complex Numbers, Taylor Series and Fourier Transform (https://moodle.warwick.ac.uk/course/view.php?id=38600)

Interdisciplinary

Combines the methods of Biology, Chemistry, Physics and computing to interrogate the mechanisms of living systems.

Subject specific skills

The ability to apply creative analytical thinking in order to frame incisive, tractable scientific questions, especially about the structures, functions and mechanisms of cells and cellular organelles.

The ability to demonstrate a grasp of physical law as it applies to the structures and behaviours of living cells and their organelles, especially nuclei.

The ability to solve problems relating to the structure and behaviours of living cells and their organelles.

Be able to describe and discuss how chemical biology and synthetic biology can be used to interrogate the mechanisms of life.

The ability to use mathematical and computational approaches to solve problems relating to biomolecular structures, functions and reactivities The ability to explain the organisation and behaviour of biomolecules, including the mechanisms by which biomolecules self-organise. The ability to design and describe simple optical circuits and to use focussed light to interrogate systems of biologically-relevant molecules.

Transferable skills

Usage of mathematical and computational approaches to solve problems.

A grasp of safety rules and an ability to work safely in the laboratory environment.

The skills to accurately record experimental procedures and results, in appropriate detail.

The skills to use computational and statistical approaches to analyse data.

The skills to access and use the scientific literature effectively.

The writing skills required to report experimental results in the format of a scientific paper.

Study

Study time

Type	Required	Optional
Lectures	30 sessions of 1 hour (7%)	
Tutorials	30 sessions of 1 hour (7%)	10 sessions of 2 hours
Practical classes	30 sessions of 3 hours (20%)	
Private study	150 hours (34%)	
Assessment	142 hours (32%)	
Total	442 hours	

Private study description

Background reading in relation to each block (set of experiments), including reading scientific papers that are then referenced in the write ups.

Costs

No further costs have been identified for this module.

Assessment

You do not need to pass all assessment components to pass the module.

Assessment group D1

	Weighting	Study time
3 x laboratory reports	40%	60 hours
Students work in pairs to carry out laboratory experiments that address unsolved scientific questions. At the end of each 2-week Block of the module, the results obtained are written up as a report in the format of a scientific paper. Each report will be 1500 words.		
Mathematical Skills	10%	10 hours
Students will be tested on their mathematical skills from Block 6 with an in-class, short-answer test based on problem sets that they have been set during this block.		
Assessment of laboratory skills	20%	72 hours
Assessing the proficiency in laboratory techniques, observing good laboratory practice, engagement and contribution to group experiments.		
Written examination	30%	

Feedback on assessment

Laboratory reports - submission annotated and returned, general comments/'what was good'/'what could be improved' alongside marking rubric.

Assessment of laboratory skills - at the end of each two-week laboratory session, block leads will provide comments on proficiency, Good Laboratory Practice (GLP) and engagement/group contribution that arise. Due to the volume of feedback, stock phrases will be provided to the block leads, which may be amended or expanded at the lead's discretion. Further verbal feedback will be given to students on request.
In terms of practicalities, following GLP, executing the laboratory protocol, attaining proficiency in techniques taught and engaging/contributing to group activities (where required) will be based at 62 on the 20-point University scale. Exceptional attainment/contributions will grade higher,

whereas disengagement, not observing GLP, and an unwillingness to acquire lab proficiency will score lower. Marks will not take into account whether a student achieved a desired experimental result or not. The block lead will work with the laboratory technician in observing and recording these across the cohort. Feedback will be provided biweekly at the end of each block.

Past exam papers for MD1A4

Availability

Courses

This module is Core for:

- Year 1 of UMDA-CF10 Undergraduate Integrated Natural Sciences (MSci)