MD1A4-45 Integrated Science Organelles and Cells

22/23

Department
Warwick Medical School
Level
Undergraduate Level 1
Module leader
Saran Shantikumar
Credit value
45
Module duration
10 weeks
Assessment
60% coursework, 40% 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.

B6 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

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 Chemical Biology
This all about seeing biology as macromolecular chemistry.

Lec1 | Arrow pushing 1

- Examine the electronic structure of reactants Harness open source software to display and examine molecular structures
  Lec2 | Arrow pushing 2
- Predicting reaction mechanisms
  Lec3 | Reaction kinetics 1
- Assemble rate equations for chemical reactions
  Lec4 | Reaction kinetics 2
- Assemble rate equations for chemical reactions
  Lec5 | Polynucleic acids
- Purines, pyrimidines, H-bonds, DNA structure, RNA structure
  Lec6 | higher order structure of proteins
- biomolecular secondary, tertiary & quaternary structure
  Lec7 | supramolecular interactions of biomolecules
- how macromolecules can interact
  Lec 8 | Cryprotection
- Molecules that modulate phase changes in liquids

Labs: labs will allow students to design and assemble carbohydrate mimetics of proteins using a thermocycler

B9 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,

B10 Cell division
How does one cell become two?
We will explore how cell division works and how it diverges across the tree of life and compare the mitotic and meiotic versions. Because this is a mechanical process we will be looking at the forces and physical processes involved. We will also look at how human life begins and the diseases associated with chromosome mis-segregation.

B10-Lec1 | Cell division and checkpoints
B10-Lec2 | Spindle mechanics
B10-Lec3 | Evolutionary divergence
B10-Lec4 | Meiosis
B10-Lec5 | Molecular genetics
B10-Lec6 | Sexual reproduction
B10-Lec7 | Write-up
B10-Lec8 | Write-up

B10-Lab1 | Experimental design and preparation
B10-Lab2 | Immunofluorescence
B10-Lab3 | Microscopy (WOSM)
B10-Lab4 | Image analysis & live cell imaging
B10-Lab5 | Data analysis & live cell imaging
B10-Lab6 | Simulations
B10-Lab7 | Write up
B10-Lab8 | Write up

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
- Describe and interpret quantitatively how chemical biology can be used to interrogate the mechanisms of life.
- Describe and discuss quantitatively the mechanisms by which chromosomes encode and transmit genetic information
- Describe and discuss quantitatively how cells replicate, recombine and segregate their genes
- 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

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

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

Computational skills. Presentation skills. Collaborative skills. Problem solving by creative analytical thinking and/or by experiment, using tools and approaches from a variety of disciplines, including Chemistry, Biology, Physics, Mathematics and Computing to frame and solve problems.

Study

Study time

Type	Required	Optional
Lectures	40 sessions of 2 hours (18%)	
Tutorials	(0%)	10 sessions of 2 hours
Practical classes	40 sessions of 3 hours (27%)	
Private study	150 hours (33%)	
Assessment	100 hours (22%)	
Total	450 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 D

	Weighting	Study time
Scientific paper	12%	20 hours

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Written examination	40%	

Feedback on assessment

Feedback is provided via Tabula using a well-specified assessment rubric that is in turn mapped to the university's assessment scale.

Past exam papers for MD1A4

Availability

Courses

This module is Core for:

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