CHEM4089: TECHNIQUES AND INSTRUMENTATION FOR CHEMICAL BIOLOGY

Effective Term
Semester A 2022/23

Part I Course Overview

Course Title
Techniques and Instrumentation for Chemical Biology

Subject Code
CHEM - Chemistry
Course Number
4089

Academic Unit
Chemistry (CHEM)

College/School
College of Science (SI)

Course Duration
One Semester

Credit Units
4

Level
B1, B2, B3, B4 - Bachelor's Degree

Medium of Instruction
English

Medium of Assessment
English

Prerequisites
Nil

Precursors
CHEM2003/BCH2003 Biochemistry

Equivalent Courses
Nil

Exclusive Courses
Nil

Part II Course Details

Abstract

Chemical biology is a discipline that studies how chemicals and chemical reactions are involved in biological processes. This discipline has overwhelmingly dominated the Nobel prize in Chemistry in the past four decades, underscoring how biological applications of chemical techniques have changed people' s lives and transformed our understanding of nature.

This course uses a problem-solving approach, in which the students will be given unknown compounds and guided to investigate the biological effects of these compounds. Through this process, the students will learn basic techniques that are commonly used in chemical biology. These include the detection of how chemicals, such as small molecules, lipids, carbohydrates, polypeptides and metals, interact with biological systems as drugs or probes, and the assessment of how the biological systems respond to the chemicals at a mechanistic level.

As an advanced undergraduate course, instead of learning these techniques individually, the students will be taught how to combine these techniques into a project. In addition, the students will experience how chemistry is combined with other fields, such as biochemistry and molecular biology, as a component of a multidisciplinary investigation. This course is ideal for students who would like to work for the biotech industry upon graduation or to develop a career as a research scientist.

Course Intended Learning Outcomes (CILOs)

	CILOs	Weighting (if app.)	DEC-A1	DEC-A2	DEC-A3
1	DESCRIBE the working principles and history of development of chemical biology.	5	x		
2	DESCRIBE the threat of antibiotic resistance to humanity in 21st century and IDENTITY the cause of the development of antibiotic resistance.	5	x	x	
3	DEVELOP the appropriate laboratory skills for measuring antibacterial activities of a chemical compound.	10	x		x
4	DESCRIBE the working principles and history of development of three groups of chemical biological techniques (see below). CRITICALLY EVALUATE these techniques for their suitability for the characterisation of the antibacterial mechanisms of selected chemical compounds.	45	x	x	
5	CREATE experimental protocols, using the selected chemical biological techniques in ILO 4, to study the antibacterial mechanisms of selected chemical compounds.	20		x	x
6	Using the data generated in this course, COMPOSE a research poster and ORALLY PRESENT it to a panel of experts.	15			x

A1: Attitude
Develop an attitude of discovery/innovation/creativity, as demonstrated by students possessing a strong sense of curiosity, asking questions actively, challenging assumptions or engaging in inquiry together with teachers.

A2: Ability
Develop the ability/skill needed to discover/innovate/create, as demonstrated by students possessing critical thinking skills to assess ideas, acquiring research skills, synthesizing knowledge across disciplines or applying academic knowledge to real-life problems.

A3: Accomplishments

Demonstrate accomplishment of discovery/innovation/creativity through producing /constructing creative works/new artefacts, effective solutions to real-life problems or new processes.

Teaching and Learning Activities (TLAs)

	TLAs	Brief Description	CILO No.	Hours/week (if applicable)
1	Lectures and in-class discussions	Students will learn in lectures and in-class discussions by examining three large groups of chemical biological techniques (bacterial counting, gene and protein expression and microscopy). For each group of techniques, students will be introduced the scientific problems involved, how scientists developed new techniques to tackle the problems, and how these new techniques led to new discoveries in science (which invaluably led to new problems that required new techniques).	1, 2, 4	
2	Lab classes	Students will be given a number of unknown chemical compounds and tasked to investigate the antibacterial effects and mechanisms of these compounds.	3, 4, 5	
3	Oral presentations	Students will be asked to prepare a poster (in the style of a conference poster) to present the outcome of their investigation.	6	

Assessment Tasks / Activities (ATs)

	ATs	CILO No.	Weighting (%)	Remarks (e.g. Parameter for GenAI use)
1	Tutorial Assignment	1, 2, 5	25	
2	Web-based Discussion / Oral Presentation / lab class performance	3, 4, 5, 6	35	

Continuous Assessment (%)

60

Examination (%)

40

Examination Duration (Hours)

3

Additional Information for ATs

Starting from Semester A, 2015-16, students must satisfy the following minimum passing requirement for courses offered by CHEM:
"A minimum of 40% in both coursework and examination components."

Assessment Rubrics (AR)

Assessment Task

Tutorial Assignment

Criterion

CAPACITY for PROBLEM-SOLVING by utilizing the concepts and techniques taught in lectures in real-life research questions

Excellent (A+, A, A-)

High

Good (B+, B, B-)

Significant

Fair (C+, C, C-)

Moderate

Marginal (D)

Basic

Failure (F)

Not even reaching marginal levels

Assessment Task

Web-based Discussion / Oral Presentation

Criterion

ABILITY to IDENTIFY scientific questions that CAN or CANNOT be solved by the chemical biological techniques and instruments introduced in this course. ABILITY to EXPLAIN the methodology and procedure published in research papers in this field.

Excellent (A+, A, A-)

High

Good (B+, B, B-)

Significant

Fair (C+, C, C-)

Moderate

Marginal (D)

Basic

Failure (F)

Not even reaching marginal levels

Assessment Task
Examination

Criterion
ABILITY to APPLY the chemical biological techniques and instruments introduced in this course to tackle real-life research problems and to ADAPT and COMBINE these techniques for original scientific questions

Excellent (A+, A, A-)
High

Good (B+, B, B-)
Significant

Fair (C+, C, C-)
Moderate

Marginal (D)
Basic

Failure (F)
Not even reaching marginal levels

Part III Other Information

Keyword Syllabus
This course consists of 13x2 hours of lectures, 13x1 hours of tutorials and 13x4 hours of lab classes. It will be a lab-driven course, in which the lectures and tutorials are designed to support the lab sessions by helping the students to analyse data and plan experiments and by providing the theoretical background of the experimental strategies used in the study. The entire course will be structured on a storyline that is modelled on the screening and characterisation of novel anti-bacterial compounds, that may include (the exact rundown of the techniques will change from year to year):

1. Drug screening (Week 1-2): At the start of the course, each student will be given a chemical compound and design an experiment to measure the toxicity of this compound, in terms of minimal inhibitory concentration (MIC), against a model (non-pathogenic) strain of Pneumonia aeruginosa (PAO1), a pneumonia-causing bacterium. The compounds used in this course will be collected from the faculties of Department of Chemistry, who are synthesising many novel molecules and nanomaterials on daily basis. After the screening, the class will select five potential hits, i.e. compounds with MIC below a particular threshold (e.g., 1uM), for further characterisation. The class will then use the following lines of investigation to characterise the effect of each compound of P. aeruginosa. The students will be divided into five teams, which are further divided into 3 groups per team. Each will be working on one of the candidate compounds. As a result, data on each compound will be in triplicate, enabling the discussion of the importance of biological variation and statistical analysis. Furthermore, the students will rotate their roles within the group, so that each student will have the opportunity to practice different transferable skills. For example, in small group discussions, each student will take different roles in turn, including facilitator, note taker, time keeper, challenger/devil' s advocate, etc.

2. Microscopy (Weeks 3-5): the students will be tasked to characterise the 5 lead-compounds by microscopy techniques. They will be guided to develop protocols for studying the effect of these compounds on the morphology (by scanning electron microscopy) and growth kinetics (by time-lapse light microscopy). Students will learn the principle and operation of advanced imaging equipment such as scanning electron microscopy, super-resolution microscopy and time-lapse confocal microscopy. Discussions will be conducted on how to infer the possible antibacterial mechanism of each compound from the observed changes in cell morphology and growth kinetics.

3. Gene expression (Weeks 6-9): the students will examine the effect of the five lead-compounds on the gene expression profile of P. aeruginosa. They will learn to perform a genome-wide RNA-seq experiment by using the Illumina iSeq100, a portable next-generation sequencing instrument that allows fast sequencing in the lab. This technique empowers our

students by giving them a hand-on experience in designing a genomic experiment and to develop the computational skills required to analyse the global change in gene expression in response to environmental perturbations.

4. qRT-PCR analysis (Weeks 10-11): from the microscopy and RNA-seq data, the students will hypothesize the possible antibacterial mechanism of each compounds. These hypotheses will be validated by targeted analysis of the expression level of representative genes of the relevant pathways. Through lab-meeting discussions, they will be guided to design PCR primers for the qRT-PCR quantitation of these genes.

5. Data summary and presentation (Weeks 12-13): each team will interpret all the data obtained from this course, discuss their significance and suggest future experiments. The whole study will be present in a poster. A poster session will be organised, in which each team to present their findings to a panel of judges (made up of faculties of the Department of Chemistry).

This course will also include the following skills:

- Presentation skills
- Technology transfer
- Entrepreneurship in science
- Open source learning in science

Reading List

Compulsory Readings

	Title
1	Nil

Additional Readings

	Title
1	Faria, Matthew, et al. "Minimum information reporting in bio–nano experimental literature." Nature nanotechnology 13.9 (2018): 777-785.
2	Lavis, Luke D., and Ronald T. Raines. "Bright ideas for chemical biology." ACS chemical biology 3.3 (2008): 142-155.
3	Schenone, Monica, et al. "Target identification and mechanism of action in chemical biology and drug discovery." Nature chemical biology 9.4 (2013): 232.
4	Spring, David R. "Chemical genetics to chemical genomics: small molecules offer big insights." Chemical Society Reviews 34.6 (2005): 472-482.
5	Wacker, Sarah A., et al. "Using transcriptome sequencing to identify mechanisms of drug action and resistance." Nature chemical biology 8.3 (2012): 235-237.
6	Falconer, Shannon B., Tomasz L. Czarny, and Eric D. Brown. "Antibiotics as probes of biological complexity." Nature chemical biology 7.7 (2011): 415-423.
7	Lewis, Kim. "Recover the lost art of drug discovery." Nature 485.7399 (2012): 439-440.