LF306-12 Synthetic Biology

21/22

Department
: Life Sciences

Level
: Undergraduate Level 3

Module leader
: John McCarthy

Credit value
: 12

Module duration
: 10 weeks

Assessment
: 30% coursework, 70% exam

Study location
: University of Warwick main campus, Coventry

Description

Introductory description

Much of bioscience is about discovery, i.e. learning about the naturally evolved properties of living systems. Synthetic biology adds a new dimension to our approach to the living world by identifying and characterizing cellular components (e.g. transcriptional elements such as promoters and transcription activators; mRNA elements such as untranslated regions or ribosome binding sites; protein domains that act as binding sites or conformational switches), and trying to assemble (engineer) these into new versions of (synthetic) biological systems. There are two major benefits to this approach. First, in the process of trying to engineer new biological systems, we improve our understanding of the naturally evolved biosphere (build-to-understand). Second, synthetic biology is in the process of radically enhancing our ability to create products and processes that are of value to human society (build-to-apply).

Synthetic biology is having a major impact on the development of applications in biotechnology, medicine, agriculture and energy, and accordingly brings academic and industrial interests together. We have therefore decided to incorporate contributions from representatives of some of our industrial partners into this module so that you can hear about commercially oriented research ‘first-hand’. Overall, this course will suit students who are interested in cutting edge science and who are keen to understand what the alternative (but related) paths of research in academia and industry might offer them in the future.

[Module web page]

Module aims

In this new module, we will introduce the core methods and principles of synthetic biology, including the design-construct-test-optimization cycle and the paradigms of build-to-understand and build-to-apply. We will then illustrate how these principles can be applied in diverse prokaryotic and eukaryotic organisms. Ideally, synthetic biologists want to be able to integrate defined biological components into functional circuits, pathways and other cellular systems that behave in predictable ways. However, biological systems are not as simple to construct as electrical circuits, and part of the fascination of synthetic biology is learning what the real rules for predictable bio-assembly are. We will also consider the rapidly developing enabling technologies of synthetic biology, including DNA synthesis and large-scale (genome) assembly methods, CRISPR and system modelling.

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.

1. Core Principles of Synthetic Biology, an overview (3 lectures)

- enabling technologies (DNA synthesis; rapid, large-scale assembly methods; CRISPR; modeling)
- build to understand and build to apply; the design-construct-test-optimization cycle
- learning from naturally occurring network motifs
- exploring functional landscapes that natural evolution may not have been able to explore
- engineering (improved?) genetic/biochemical circuitry; predicting and observing behaviour
- complexity/limitations of naturally evolved biology, e.g. lack of orthogonality, stochasticity, heterogeneity, energetic considerations, scalability
- the limits of the engineering paradigm in biology; can these be overcome?
- the challenges of standardization
- the scope of things to come

1. Microbial cells as hosts for circuitry and pathways (6 lectures)

- circuitry designs in bacteria and yeasts; components extending from DNA through RNA to protein
- predicted and actual behavior of engineered systems
- experimental and computational tools available to characterize natural and engineered systems
- whole genome engineering (and recoding)
- cell-cell interactions, quorum sensing, microbial communities
- applications of microbial engineered circuits, pathways and genomes in medicine, the environment, biotechnology (biosensors, biofuels, biomaterials, high value chemicals etc)
- how can we make engineered biological systems behave predictably?

1. In vitro systems (and the origin of life) (2 lectures)

- In vitro transcription and translation systems

- Minimal self-reproducing (and evolving) physicochemical systems
- Alternative genetic materials (e.g. xenoDNA)

1. Computation Class: The Design-Construct-Test-Optimise cycle (1 afternoon sessions) Students will be given an overview of the principles of circuitry design. The value of the design-construct-test-optimise cycle will have been illustrated in previous lectures in the context of a range of specific applications. These lectures will also have commented on the challenges inherent in trying to ‘engineer’ biology. Working in groups, the students will then be given the opportunity to incorporate a (limited) number of alternative components into the design of a simple circuit in E.coli. Modelling will be used to predict system behavior, and the class will conclude with short presentations from the students on their modeled systems, coupled to a discussion of the reasons why real experimental biological systems do not behave in accordance with simple models and how this problem can be addressed.

2. Synthetic Biology in more complex organisms: From Plants to Humans (6 lectures)

- mammalian cell engineering – e.g. T cell engineering and medical applications
- optogenetics
- interspecies communication (molecular signaling between microbial and mammalian cells)
- plant synthetic biology: synthetic sensors, metabolic pathways, genomes, with key examples related to food, biomass, biofuels, polymers, drugs.

1. Ethical, Legal and Societal aspects of Engineering Biology (1 lecture)

- Like AI, SynBio has the potential to be a disruptive force, changing the underpinning philosophy of bioscience, generating potentially both good and bad outcomes, creating ethical and legal challenges. We need to engage the students in a discussion of these complex issues.

Learning outcomes

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

- The relationship between design, construction, testing and optimization in a biological context. The concept of standardisation and its (limited) applicability. The potential of synthetic biology to revolutionize the discovery process in biology and to enable step-change advances in biotechnology, medicine, food security and the environment.

Subject specific skills

a. Demonstrate clear understanding of the scientific topic

b. Contain evidence of extended reading and lateral integration of material not covered in the lectures

c. Demonstrate independent thought and deep understanding

d. Specifically answer the set question using information from multiple lectures and sources

e. Be structured and formatted in a way that demonstrates understanding and logical flow

f. Use multiple sources to construct complex scientific arguments and integrating these to build and develop the student's own scientific conclusions.

Transferable skills

1. Critical appraisal of source material
2. Self directed learning
3. Adult learning

Study

Study time

Type	Required
Lectures	20 sessions of 1 hour (17%)
Private study	100 hours (83%)
Total	120 hours

Private study description

Independent learning, self directed learning and revision for final year exams.

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
1 hr (MCQ; In-Module)	30%	
Written Examination	70%	

EXAM: ESSAY BASED EXAM- STUDENTS NEED TO ANSWER 2 OUT OF 4 SET QUESTIONS IN 1.5 HRS

Feedback on assessment

Grades and feedback will be provided within 20 working days of the deadline (as imposed by the university). Working days are Monday - Friday and do not include public holidays or University closure days.

Past exam papers for LF306

Availability

Courses

This module is Option list A for:

- Year 3 of UBSA-C700 Undergraduate Biochemistry
- ULFA-C1A2 Undergraduate Biochemistry (MBio)
  - Year 3 of C1A2 Biochemistry
  - Year 3 of C700 Biochemistry
- UBSA-3 Undergraduate Biological Sciences
  - Year 3 of C100 Biological Sciences
  - Year 3 of C100 Biological Sciences
- Year 3 of ULFA-C1A1 Undergraduate Biological Sciences (MBio)
- UBSA-C1B9 Undergraduate Biomedical Science
  - Year 3 of C1B9 Biomedical Science
  - Year 3 of C1B9 Biomedical Science
  - Year 3 of C1B9 Biomedical Science
- ULFA-C1A3 Undergraduate Biomedical Science (MBio)
  - Year 3 of C1A3 Biomedical Science
  - Year 3 of C1B9 Biomedical Science