Synthetic Biology Systems in theory and in practice Course proposal

Abstract

A multidisciplinary course that combines seven areas of science and engineering giving undergraduates a solid foundation in a cutting edge field of biological engineering.

Background

In 1978 the Nobel Prize in Medicine was awarded to Daniel Nathans and Hamilton Smith and it was predicated that "*the new era of synthetic biology"* had arrived , where genes could be cut up, changed around and put back together again to form novel function. However it was not until 2000 that the first examples of an engineered biological circuits were published in Nature. One was a synthetic oscillator[1]; an engineered strain of E.coli capable of cyclic expression of green fluorescent protein, the other was a bacterial toggle switch[2] capable of switching the protein to be expressed into one of two states. Since then engineers' interest and contributions to biology have created a completely new field of 'synthetic biology'.

Synthetic biology is a mixture of biology, chemistry, engineering, genetic engineering and biophysics. It builds on recent work in systems biology which involves the modeling of biological systems, but goes further in that it involves the construction and standardization of biological parts, that fit together to form more complex systems. One of the key factors that is making synthetic biology a reality is the falling cost of two key technologies, sequencing of DNA (now just $7 per read) and synthesis of novel DNA (now $0.69 per base pair). This fall in price continues to halve about every 18 months and was recently compared to the doubling of the number of processors being put onto computer chips[3] which also happens every 18 months (see figure below). If this pace of development continues then not only is a new field of science and engineering forming but also a new industrial revolution, based on smaller, cleaner biological machines.

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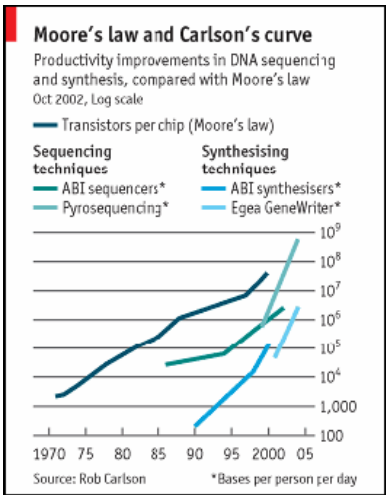
[1] Elowitz MB, Leibler S. A synthetic oscillatory network of transcriptional regulators. Nature. 2000 Jan 20;403(6767):335-8.

[2] Gardner TS, Cantor CR, Collins JJ. Construction of a genetic toggle switch in Escherichia coli. Nature. 2000 Jan 20;403(6767):339-42.

[3] The Economist, Aug 31st 06.



Left, Synthetic Biology on the cover of Nature, 24th Nov 05.
Right, DNA synthesis and sequencing from The Economist, Aug 31st 06.

Course aim
This course will aim to give students a thorough grounding in the literature of synthetic biology as well as provide them with an up-to-date framework in systems biology.

The course will give students the theory and techniques needed to mathematically model biological systems and teach them the biological engineering principles needed to build them.

Logistics
The course will be taught by an interdisciplinary group of Brown faculty with the support of a graduate teaching assistant. Meeting twice a week, the course will begin with overview lectures of the field. Each faculty will then give one lecture of overview in their specialized area followed by a seminar/discussion of primary literature in the area.

	Proposed faculty	**Topic**	**Department / area**
1	Gary Wessel	Overview and Bioethics	MCB
2	Wolfgang Peti (tbc)	Protein engineering	MPPB
3	Marc Johnson	Bioenergy	MCB
4	Tayhas Palmore (tbc)	Principles of Engineering	Biomedical Engineering
5	Tom Webster	Nanotechnology	Biomedical Engineering
6	Jay Tang	Microbial forces	Physics
7	Nicola Neretti	Deterministic models	Physics
8	Alex Brodsky (tbc)	Techniques in synthetic biology I	MCB
9	Jeff Morgan (tbc)	Techniques in synthetic biology II	MPPB
10	Jim Head III (tbc)	Astrobiology	Geology

11	Suzanne Sindi	Stochastic Modeling	Applied Mathematics
12	Woods Hole visit	Exploring Microbiology	
13	Jason Sello	Organic Synthesis	Chemistry
14	David Cane (tbc)	Metabolic Engineering	Chemistry
15	Sherief Reda	Engineering systems	Electronic Engineering

(tbc = to be confirmed)

In addition, Karen Haberstroh has agreed to help with the course logistics and in helping to oversee the success of the student experience.

Who

The course is intended for third year undergraduates with a suitable background in either science of engineering.

Assessment

Bi-weekly problem sets based on assigned reading and lectures, covering key concepts, designing problems and practical modeling exercises, one midterm exam covering the topics in the first part of the course, two papers, one a critical summary of the field of interest, and the second a creative application of the students interest.