

Synthetic Biology Courses Taught by SynBERC Faculty

Synthetic biology is an emerging field; as such, we anticipate that curriculum and academic program development will continue to evolve over time. We have developed a “map” of the fundamental areas that we believe are necessary for any synthetic biologist to master:

- Analysis of existing biological systems
- Design of new biological systems
- Construction of biological systems
- Characterization of biological systems
- Societal aspects of synthetic biology

Some of these fundamentals are covered in foundational biology and engineering courses that already exist in the undergraduate curricula. Others covering current state-of-the-art issues in synthetic biology will evolve as research advances and technology and innovation occur. SynBERC’s core and outreach institutions have very different academic structures, departments, courses, and mechanisms for initiating new courses and programs of study. We believe that this is one of SynBERC’s strengths, as it necessitates that we develop a curricular framework that is responsive to real-world dynamics and technological innovation, as well as being applicable across a range of settings and needs.

Synthetic biology-related courses taught by SynBERC faculty at SynBERC’s core and partner institutions are listed below. Foundational courses in engineering and the physical and biological sciences are omitted. Courses developed over the past year as well as those that have had synthetic biology-related content added to them over the past year are asterisked.

UC Berkeley

Bioengineering, BioE 140L Synthetic Biology Lab "SynBio Bootcamp" (Instructor: J.C. Anderson). This new laboratory course is designed as an introduction to research in synthetic biology, a ground-up approach to genetic engineering with applications in bioenergy, healthcare, materials science, and chemical production. In this course, we will design and execute a real research project. Each student will be responsible for designing and constructing components for the group project and then performing experiments to analyze the system. In addition to lab work, we will have lectures on methods and design concepts in synthetic biology including an introduction to Biobricks, gene synthesis, computer modeling, directed evolution, practical molecular biology and biochemistry. The course will be taught for the first time in spring 2009.

http://sis.berkeley.edu/catalog/gcc_list_crse_req?p_dept_name=Bioengineering&p_dept_cd=BIO+ENG

Bioengineering, BioE 190D/290D, Frontiers in Microbial System Biology (Instructor: Arkin). This course covers current topics of research interest in bioengineering. The course content may vary from semester to semester.

http://sis.berkeley.edu/catalog/gcc_list_crse_req?p_dept_name=Bioengineering&p_dept_cd=BIO+ENG

Chemical Engineering 162 Dynamics and Control of Chemical Processes. (Instructor: Keasling). Analysis of the dynamic behavior of chemical processes and methods and theory of their control. Implementation of computer control systems on laboratory processes and process simulations. First offered: 1994 (appears in campus database for first time in 2005).

http://chemistry.berkeley.edu/stud_info/course_info/cheme_classes.html

Chemical Engineering 170L Biochemical Engineering Laboratory. (Instructor: Keasling). Design, operation, and analysis of process in the biochemical industries. Fermentation and recovery of biochemical products. First offered in 1995; as of 2003, the course was cross-listed with chemistry.

http://chemistry.berkeley.edu/stud_info/course_info/cheme_classes.html

Chemical Engineering 196 Synthetic Biology/iGEM. (Instructors: Keasling, Arkin). Special laboratory study under direction of faculty. First offered spring 2005.

http://chemistry.berkeley.edu/stud_info/course_info/cheme_classes.html

Chemical Engineering C295/Bioengineering C230 Implications and Applications of Synthetic Biology. (Instructors: Arkin, Keasling). Explore strategies for maximizing the economic and societal benefits of synthetic biology and minimizing the risks; create “seedlings” for future research projects in synthetic biology at UC Berkeley; increase multidisciplinary collaborations at UC Berkeley on synthetic biology; and introduce students to a wide perspective of synthetic biology projects and innovators as well as policy, legal, and ethical experts. First offered spring 2007. Enrollment: 30.

http://chemistry.berkeley.edu/stud_info/course_info/chem_classes.html

Molecular and Cell Biology 113 Applied Microbiology and Biochemistry. (Instructors: Keasling, Nikaido). A survey of modern developments emphasizing the application of the knowledge of fundamental microbiology to industrial processes. Topics include production of metabolites, enzymes, and single-cell proteins; genetic manipulation of microorganisms; recovery of minerals; and energy production. First offered in 1991. http://sis.berkeley.edu/catalog/gcc_search_sends_request

Molecular and Cell Biology 206 Physical Biochemistry. (Instructors: Bustamante, Marqusee, Doudna). Application of modern physical concepts and experimental methods to the analysis of the structure, function, and interaction of large molecules of biological interest. First offered in 1989.

http://sis.berkeley.edu/catalog/gcc_search_sends_request

Molecular and Cell Biology 290 Single Molecule Biophysics. (Instructor: Bustamante). Methods of single molecule manipulation and visualization that are used to characterize the structure and mechanochemical properties of translocating DNA binding protein such as RNA polymerase and to investigate the mechanical denaturation of single protein molecules will be covered in research reports and reviews of the current literature and in discussion of current experiments in the field. One time seminar.

http://sis.berkeley.edu/catalog/gcc_search_sends_request

Physics 177 Principles of Molecular Biophysics. (Instructor: Bustamante). Overview of the structure of proteins, nucleic acids, carbohydrates, lipids, and the forces and interactions maintaining their structure in solution from the approach of a physicist. The thermodynamics and kinetics of protein folding, the principles of polymer chain statistics and of helix-coil transitions in biopolymers, and biopolymer dynamics will be covered. The main structural methods in biology are covered: X-ray crystallography, MNR and fluorescence spectroscopy, electron and probe microscopy, and single molecular methods. First offered spring 2000. http://sis.berkeley.edu/catalog/gcc_search_sends_request

Anthropology 112B Synthetic Biology Anthropology. (Instructor: Rabinow). The first goal of the class is to equip students to be able to think about the relations among three registers: Synthetic Biology, Concepts and Cases. The second goal is to equip students to work on problems collaboratively in a mode of human practices. The course is designed such that the student will be prepared to address the question of what is distinctive about the synthetic biology approaches to problem areas such as malaria, biofuels, security, tumor killing bacteria, intellectual property and what are some of the associated human practices challenges? The class is to produce a casebook of 4 group projects which will focus on topic areas central to synthetic biology. These 4 topic areas are; “environment”, “IP”, “health” and “safety, security, preparedness”. The class will be divided into four research teams corresponding to these topic areas.

http://openwetware.org/images/6/66/Synthetic_Biology_Syllabus.pdf

Anthropology 198 Undergraduate Human Practices Research Projects (Instructors: Rabinow, Bennett, Stavrianakis). The success of the undergraduate human practices course (Anthro 112) resulted in six advanced undergraduate students from the course seeking to conduct longer-term research projects. Like the course, these undergraduates consist of both biologists and non-biologists, and the research projects focus on core themes in synthetic biology. First offered spring 2007. Enrollment: 6.

http://sis.berkeley.edu/catalog/gcc_search_sends_request

Anthropology 250 Graduate Seminar: Diagnostic Equipment and Comparative Anthropological Inquiry. (Instructor: Rabinow). The seminar introduced graduate students to the Human Practices Diagnostic for

Synthetic Biology. The diagnostic was used to conduct comparative and to orient collaborative case studies in synthetic biology and related domains. In addition to the case studies, the course functioned as proof of concept for the usefulness and generalizability of the human practices diagnostic. First offered fall 2007. Enrollment: 14. http://sis.berkeley.edu/catalog/gcc_search_sends_request

UCSF

Biochem 205 Introduction to Dynamical Systems. (Instructor: Voigt). This course introduces quantitative modeling of complex dynamical biochemical systems. Students will be able to model systems involving coupled biochemical reactions & reduce them to dimensionless variables. For linear systems students will be able to model systems using Laplace transforms; for nonlinear systems, perform an analysis of stabilities & robustness. They will understand 1) how biochemical reaction networks can function in the presence of noise & 2) signal processing in biology. <http://student.ucsf.edu/genecat/BP.html>

BMI 206 Bioinformatics and Computational Biology. (Instructors: Kortemme, Babbitt, Sali). This is the first of two theory courses required for all UCSF students in a new integrative program in Quantitative Biology. The course covers principles and applications in bioinformatics and computational biology. An expanded module in foundational technologies for molecular design of protein function (parts design) was added in 2007. Enrollment: 11 winter 2007; 20 winter 2008. <https://www.cgl.ucsf.edu/bmi206/>

Cellbio 245 Cell Biology (Instructor: Lim). The course will not survey all of cell biology but will rather focus on a few selected exciting topics in cell biology. Particular emphasis will be placed on emerging concepts concerning cell organization, structure and function and on how complex problems can be approached experimentally. The lecturers will assume that students are familiar with basic biochemistry, genetics, and molecular biology through previous course work. http://cellbio.ucsf.edu/course_info/courseinfo.php

Pharmacology 121 Pharmaceutical Chemistry (Instructor: Lim). The basic focus of this course is consideration of structure-function relationships in various drug classes and their antagonists involved in treatment of endocrine diseases and in the inhibition of inflammation and immune response. <http://course.ucsf.edu/pc121/>

MIT

10.442/10.542 Biochemical Engineering (Instructor: Kristala Jones Prather). This course focuses on the interaction of chemical engineering, biochemistry, and microbiology. Mathematical representations of microbial systems are featured among lecture topics. Kinetics of growth, death, and metabolism are also covered. Continuous fermentation, agitation, mass transfer, and scale-up in fermentation systems, and enzyme technology round out the subject material. <http://ocw.mit.edu/OcwWeb/Chemical-Engineering/10-442Spring-2005/CourseHome/>

20.020 Introduction to Biological Engineering Design (Instructor: Kuldell). A project-based introduction to the engineering of synthetic biological systems for would-be biological engineers as well as a foundational framework for anyone interested in the responsible and reliable programming of genetic material. Students develop projects that are responsive to real-world problems, using solutions that depend on biological technologies. Topics include (1) components and control of cellular behavior, in particular energy, modularity and heredity through time and space (2) DNA synthesis, standards, and abstraction in biological engineering (3) issues of human practice, including biological safety, security, ownership, sharing, & innovation, and ethics. This subject will be taught for the first time in spring 2007 through a grant from the d'Arbeloff Fund for Excellence in Education. <http://openwetware.org/wiki/20.20>

20.109 (aka BE.109) Laboratory Fundamentals of Biological Engineering. (Instructor: Kuldell). An introduction to experiments and techniques in biological engineering. Students gain confidence and familiarity with some fundamental experimental approaches and lab protocols. They also develop good habits at the bench, learn good scientific practice, gain some experience with report writing, notebook

keeping and publicly presenting data. This subject is taught every term and experimental modules in synthetic biology have been taught every year since 2006. The initial module was developed from Alumni Class Funds for Teaching and Education Enhancement.

[http://openwetware.org/wiki/20.109\(F07\):Module_1](http://openwetware.org/wiki/20.109(F07):Module_1);

http://openwetware.org/wiki/BE.109:Systems_engineering

BE.180 (aka 20.180) Biological Engineering Programming (Instructor: TBD). Students learn how to solve complex biological engineering problems using computational approaches, and also discover the rudiments of how to program DNA, the genetic material that runs inside all living organisms. Students are also exposed to powerful ideas that underlie all of modern engineering. (This course is no longer being taught).

<http://openwetware.org/wiki/20.180>

20.181 Biological Engineering Computation (Instructor: TBD). This course covers the analytical, graphical, and numerical methods supporting the analysis and design of integrated biological systems. Topics include modularity and abstraction in biological systems, mathematical encoding of detailed physical problems, numerical methods for solving the dynamics of continuous and discrete chemical systems, statistics and probability in dynamic systems, applied local and global optimization, simple feedback and control analysis, statistics and probability in pattern recognition. (This course is no longer being taught).

<http://openwetware.org/wiki/20.181>

20.902/20.947 Advanced Topics in Synthetic Biology (Instructor: Kuldell). This special seminar is a sister course that is offered in conjunction with 20.020. 20.902/20.947 is intended for advanced undergraduates or graduate students across multiple majors. Coursework will include (a) reading, presentation, and discussion of primary synthetic biology research literature, and (b) advising and mentorship of a small undergraduate team comprised of 20.020 students. The goals for 20.902/20.947 students will be to gain an in depth understanding of the state of research in synthetic biology, develop or refine skills needed to critically read, present, and discuss primary research literature, and develop or improve skills for managing and leading small teams. (First offered in spring 2008). http://openwetware.org/wiki/20.20:Advanced_topics

STS.909 History, Philosophical and Sociological Aspects of Synthetic Biology (Instructor: Evelyn Fox Keller). This course will be offered for the first time in January 2008 during Independent Activities Period and has been organized by Evelyn Fox Keller. It features lectures and discussions led by SynBERC investigators including Drew Endy, Kenneth Oye, and Larry McCray, and SynBERC graduate students including Rachel Wellhausen, Gautam Mukunda, and Michael Rossi. <http://student.mit.edu/searchiap/fs-sts-909.html>

17.310/ESD.103/STS.482 and 17.31J Science, Technology and Public Policy (Instructor: Ken Oye). Analysis of issues at the intersection of science, technology, public policy, and business. In the fall of 2007, synthetic biology content was added to the framework of this course. Synthetic biology content included: applicability of patents and copyright to DNA fragments and biological parts with functions specified; case materials on biofuels and drug production work by SynBERC investigators; technical standards and protocols in synthetic biology; technical studies on risk appraisal associated with synthesis and synthetic biology. <http://student.mit.edu/catalog/mSTSa.html>

Harvard

MCB 100 Synthetic Biology (Instructor: Church). Course goals: Fix the non-working BioSketch assembly; assemble an alternative BioSketch assembly; research potential sensors that can work in bacteria and clone them into a usable form; design a generic modular system to test and characterize the sensors; connect the sensors to BioSketch (e.g. imagine sketching with ethanol instead of UV).

<http://openwetware.org/wiki/MCB100>

Biophysics 101 Genomics, Computing, and Economics. (Instructor: Church). Focuses on modern technologies with exponential growth and their impact on global quality of life through weekly updated Wiki class project (in-depth case studies on personal genomics and/or biofuels). Integrating knowledge, tools for research, and commercial decision-making concerning new aspects of bioengineering, personalized

medicine, genetically modified organisms, and stem cells. Interplays of biophysical, ecological, economic, and social/ethical modeling will be explored through multi-disciplinary teams of students, and individual brief reports. http://openwetware.org/wiki/Harvard:Biophysics_101/2008

Biophysics 242 Synthetic Biology: Cellular and Molecular Engineering. (Instructors: Zostak, Silver, guest speaker, Church). Synthetic biology explores the design rules for building artificial behavior of biomolecular systems through cycles of construction and comparison of intended versus observed behaviors. The ability to synthesize biomimetic behavior is an important benchmark for biological understanding. This course introduces strategies for engineering cellular and molecular systems and explores current and future applications for synthetic biology approaches. http://openwetware.org/wiki/Harvard:Synthetic_Biology_Nanocourse/2007

Prairie View A&M University

BIOL 3134. Synthetic Biology (Instructor: Cuero) Open to graduate and undergraduate students from any discipline. The interdisciplinary study of the implementation and application of synthetic biology applied to the design and construction of new biological parts, devices and systems. Laboratory is required. This course is planned for fall 2009.

CHEG 4103 Introduction to Biotechnology and Bioprocess Engineering. (Instructor: Gyamerah). Developments in genetics and molecular biology have spurred interest in biotechnology. Achievement of the full benefits of biotechnology however, requires substantial manufacturing capability involving large-scale processing of biological material. Employment of graduates trained in biochemistry, microbiology, molecular genetics and the biological sciences by companies to work in cooperation with biochemical engineers and chemical engineers highlights the multidisciplinary nature of bioprocessing. This course is designed to provide the student of chemical engineering, biological sciences and chemistry training to ensure effective communication, hands-on skills, and analytical tools necessary for a successful career in the biological/biochemical and biopharmaceutical process industries.

New class 06-08	Syn bio content added 06-08		Analysis-existing systems	Design - new systems	Construction of systems	Characterization of systems	Human Practices/Societal aspects
		Berkeley					
•		Bioengineering, BioE 140L Synthetic Biology Lab "SynBio Bootcamp" (UG)		•	•	•	•
•		Bioengineering, BioE 190D Frontiers in Microbial System Biology	•	•	•	•	
		ChemE162 Dynamics & Control of Chemical Processes (UG)	•	•	•		
		ChemE170 Biochemical Engineering Lab (UG)		•	•	•	
		ChemE196 Synthetic Biology/iGEM (UG)	•	•	•	•	
		ChemE295/BioE230 Implic. & Applic. of Synthetic Biology (G)	•	•	•	•	•
		MCB113 Applied Microbiology & Biochemistry (UG)	•		•	•	
		MCB206 Physical Biochemistry (G)	•	•		•	
		MCB290 Single Molecule Biophysics (G)	•			•	
		Physics177 Principles of Molecular Biophysics (UG)	•			•	
•	•	Anthro112B Synthetic Biology Anthropology (UG)	•	•		•	•
•		Anthro198 Undergrad Human Practices Research Projects (UG)	•	•		•	•
•		Anthro250 Diagnostic Equip & Comp Anthrop. Inquiry (G)	•	•		•	•
		UCSF					
•	•	Biochem 205 Introduction to Dynamical Systems	•	•		•	
	•	BMI206 Bioinformatics and Computational Biology	•	•		•	
	•	Cellbio 245 Cell Biology		•	•	•	
	•	Pharmacology 121 Pharmaceutical Chemistry		•	•	•	
		MIT					
•		20.020 Introduction to Biological Engineering Design	•		•	•	•
	•	20.109 Lab Fundamentals of Biological Engineering	•	•	•	•	•
		20.180 Biological Engineering Programming	•				
		20.181 Biological Engineering Computation	•				
•		20.920 Advanced Topics in Synthetic Biology	•	•		•	•
•		STS.909 History, Philos. & Sociol. Aspects of Synthetic Biology					•
	•	STS.482 Science, Technology & Public Policy					•
		Harvard					
•	•	MCB 100 Synthetic Biology	•	•	•	•	
	•	Biophysics 101 Genomics, Computing & Economics	•	•			•
	•	Biophysics 242 Synthetic Biology: Cellular and Molecular Engineering	•	•	•		
		Prairie View					
		Cheg4103 Introd. to Biotechnology & Bioprocess Engineering	•	•	•		
•		BIOL 3134 Synthetic Biology		•	•	•	

