TO: The Faculty of the College of Engineering

FROM: The School of Agricultural and Biological Engineering

RE   Curriculum Changes - Biological Engineering Plan of Study

The faculty of the School of Agricultural & Biological Engineering has approved the establishment of three majors for students in the Biological Engineering degree program: Food and Biological Process Engineering (FBPE), Pharmaceutical Process Engineering (PPE), and Cell & Biomolecular Engineering (CBE). Currently all students in our Biological Engineering degree program have a major of Biological and Food Process Engineering. This action is now submitted to the Engineering Faculty with a recommendation for approval.

Differences in requirements for the three majors: The primary differences among the three majors are summarized in the table below and include core biology, science, core engineering, and recommended technical electives as well as project topics within shared core courses as summarized below. These changes would apply to students entering the School of Engineering in the Spring 2012 and thereafter.

	FBPE	PPE	CBE
Biology Core	BIOL 11000 Fund. Of Biology I (4)	BIOL 11000 Fund. Of Biology I (4)	BIOL 23000 Cell Biology (3) OR BIOL 23100 Cell Biology OR BCHM 30700
	Biol 22100 Microbiology (4)	Biol 22100 Microbiology (4)	IT 22600 Biotechnology Lab (2)
		BCHEM 30700 Biomolecules (3)	Biology Elective (3)
Science Elective	FN 20500 Food Science (3)	IPPH 36200 Basic Pharmaceutical I (3)	CNIT 22700 Bioinformatics (2)
	Bio/Food Science Elective (4)	IPPH 36300 Basic Pharmaceutical II (3)	Life Science Elective (3)
	Bio/Food Science Elective (4)	IPPH 5620 Introduction to Mfg Process (3)	Life Science Elective (3)
Core Engineering	No changes	No changes	ABE 49500 Cell & Molecular Design Principles (3)
Engineering Selective*	Selected from*: ABE 45000 Finite Element Method in Design and Opt. (3) CE 35000 Environmental Engineering (3) IE 34300 Engineering Economics (3 cr.) ME 41800 Engineering of Environmental Systems and Equipment (3 cr.) ABE 53100 Instrumentation and Data Acquisition (3 cr.)	Selected from*: CHE 30600 Design of Staged Separation Processes (3) IE 34300 Engineering Economics (3) CHE 52500 Biochemical Engineering (3) CHE 53600 Particulate Systems (3) IE 37000 Manufacturing Processes I (3)	Selected from*: ABE 59100T Biophysics (3) ABE 59100 Engineering Approaches to Systems Biology (3) CE 35000 Environmental Engineering (3) ABE 56000 Biosensors (3) ABE 49800 Undergrad Research (3) BME 49500/MA49500 Comp. Cell Biology (3) BME 47000 Biomolecular Engr ABE 59100W/BME 59500U Nonlinear Dynamics in Biological Systems (3)
total	22 credits	23 credits	22 credits

* not a complete list

Justification: For many ye ars, ABE h as o ffered five-year dual m ajor programs with Pharmaceutical S ciences an d B iochemistry i n addition t o t he f our-year Biological a nd Food Process E ngineering major. G raduates ha ve w orked i n the f ood, p harmaceutical an d biotechnology industries. The significant growth of biological engineering as a field, along with a desire maintain a reasonable time to graduation for the majority of our students creates a need for four-year programs in these areas. In addition, the availability of only one major has limited the evolution, divergence and growth of the pharmaceutical and cell/biochemistry aspects of the degree program. The creation of three majors will enable this future growth and allow for four-year programs t hat s erve our ba se industries. The r etention of the Food a nd B iological Process major will maintain the visibility of the food program among current and potential students and sustain our l inkages with t he m any food i ndustry companies w ho r egularly r ecruit a t P urdue. Finally, t he growth of t he B E pr ogram ha s pl aced r esource constraints on e xperiential c ourses (e.g. Biotchnology Lab) that were previously required for all students.

A rapid and steady growth of interest of the incoming class in Biological Engineering is constent with these wider industry and academic trends. The biological engineering sophomore class has roughly tripled in the last 6 years. When asked about their area of interest, 26% of the 2011 s ophomore c lass s aid "Food P rocess," 25 % s aid "Biological E ngineering (generic)," an d 23% said "Cell and Biomolecular."

Cell & Biomolecular Engineering is the design, modification, and analysis of microorganisms from all domains of life (Eukaryota, Bacteria, and Archaea) and the integration of these cells into devices, reactors, and processes to produce fuels, cell products, and biotech products, along with biosensors, that can be used to meet global challenges in the environment, agriculture, energy, health, and sustainability. Students in this field will pursue careers in bio-based products, biologics, bioenergy, biotechnology and graduate school.

Pharmaceutical Engineering. Our Department established a dual degree with Pharmaceutical Sciences in 1996 and a significant number of our ABE graduates are currently working in the pharmaceutical industry. The establishment of a *Pharmaceutical Process Engineering* major provides a four-year option for students who want to work in the pharmaceutical industry.

Food and Biological Process Engineering major will allow us to maintain the visibility of this program among current and potential students. We have a large number of graduates currently working in R&D, manufacturing, quality control, and entrepreneurship in the food industry. Retention of the major will help us to sustain the connections our Department has established with the many food industry companies who regularly recruit at Purdue.

Minimum Degree Requirements for Food and Biological Process Engineering Major
Credit Hours Required for Graduation

Present	Total Credit Hours	135	Proposed	Total Credit Hours	135
Courses		*Credit Hours*	*Courses*		*Credit Hours*
Mathematics and Basic Sciences			**Mathematics and Basic Sciences**		
Calculus: MA16500, 16600, 26100, 26500, 26600		18	Calculus: MA16500, 16600, 26100, 26500, 26600		18
Chemistry: CHM 11500, 11600, 25700		12	Chemistry: CHM 11500, 11600, 25700		12
Physics: PHYS 17200, 24100		7	Physics: PHYS 17200, 24100		7
Biological and Food Sciences			**Biological and Food Sciences**		
Biological Sciences: BIOL 22100, 23000, IT 22600		9	Biological Sciences: BIOL 11000, 22100		8
BCHM 22100 or FN 20500		3	FN 20500		3
Biological or Food Science Selectives		7	Biological or Food Science Selectives		8
Engineering Tools and Skills			**Engineering Tools and Skills**		
ENGR 13100, ENGR 13200, CHE 32000		7	ENGR 13100, ENGR 13200, CHE 32000		7
Professional Development			**Professional Development**		
ABE 29000, 49000		2	ABE 29000, 49000		2
Communication			**Communication**		
English Composition: ENGL 10600		4	English Composition: ENGL 10600		4
Speech: COM 11400		3	Speech: COM 11400		3
Humanities and Social Sciences General Education Must be chosen in accordance with the approved general education list and with the help of a faculty advisor. Of the 18 credit hours, 6 must meet College of Agriculture international understanding requirements, 3 must be an additional communication elective, and 3 must be economics		18	**Humanities and Social Sciences General Education** Must be chosen in accordance with the approved general education list and with the help of a faculty advisor. Of the 18 credit hours, 6 must meet College of Agriculture international understanding requirements, 3 must be an additional communication elective, and 3 must be economics		18
Core Engineering Courses			**Core Engineering Courses**		
Thermodynamics: ABE 20100, 20200, 30100, 30300		13	Thermodynamics: ABE 20100, 20200, 30100, 30300		13
Momentum, Heat and Mass Transfer: CHE 37700, 37800		8	Momentum, Heat and Mass Transfer: CHE 37700, 37800		8
Kinetics and Reaction Engineering: ABE 37000		3	Kinetics and Reaction Engineering: ABE 37000		3
Sensors and Process Control: ABE 460000		3	Sensors and Process Control: ABE 460000		3
Transport Processes: ABE 45400		4	Transport Processes: ABE 45400		4
Unit Operations: ABE 55500		4	Unit Operations: ABE 55500		4
Biological and Food Process Design: ABE 55600		4	Biological and Food Process Design: ABE 55600		4
Process Engineering: ABE 58000		3	Process Engineering: ABE 58000		3
Technical Electives		**3**	**Technical Electives**		**3**

Minimum Degree Requirements for Pharmaceutical Process Engineering
Credit Hours Required for Graduation

Present	Total Credit Hours	135	Proposed	Total Credit Hours	136
Courses		*Credit Hours*	*Courses*		*Credit Hours*
Mathematics and Basic Sciences			**Mathematics and Basic Sciences**		
Calculus: MA16500, 16600, 26100, 26500, 26600		18	Calculus: MA16500, 16600, 26100, 26500, 26600		18
Chemistry: CHM 11500, 11600, 25700		12	Chemistry: CHM 11500, 11600, 25700		12
Physics: PHYS 17200, 24100		7	Physics: PHYS 17200, 24100		7
Biological and Food Sciences			**Biological &Pharmaceutical Sciences**		
Biological Sciences: BIOL 22100, 23000, IT 22600		9	Biological Sciences: BIOL 11000, 22100		8
BCHM 22100 or FN 20500		3	BCHM 30700		3
Biological or Food Science Selectives		7	IPPH 36200, 36300, 56200		9
Engineering Tools and Skills			**Engineering Tools and Skills**		
ENGR 13100, ENGR 13200, CHE 32000		7	ENGR 13100, ENGR 13200, CHE 32000		7
Professional Development			**Professional Development**		
ABE 29000, 49000		2	ABE 29000, 49000		2
Communication			**Communication**		
English Composition: ENGL 10600		4	English Composition: ENGL 10600		4
Speech: COM 11400		3	Speech: COM 11400		3
Humanities and Social Sciences General Education Must be chosen in accordance with the approved general education list and with the help of a faculty advisor. Of the 18 credit hours, 6 must meet College of Agriculture international understanding requirements, 3 must be an additional communication elective, and 3 must be economics		18	**Humanities and Social Sciences General Education** Must be chosen in accordance with the approved general education list and with the help of a faculty advisor. Of the 18 credit hours, 6 must meet College of Agriculture international understanding requirements, 3 must be an additional communication elective, and 3 must be economics		18
Core Engineering Courses			**Core Engineering Courses**		
Thermodynamics: ABE 20100, 20200, 30100, 30300		13	Thermodynamics: ABE 20100, 20200, 30100, 30300		13
Momentum, Heat and Mass Transfer: CHE 37700, 37800		8	Momentum, Heat and Mass Transfer: CHE 37700, 37800		8
Kinetics and Reaction Engineering: ABE 37000		3	Kinetics and Reaction Engineering: ABE 37000		3
Sensors and Process Control: ABE 460000		3	Sensors and Process Control: ABE 460000		3
Transport Processes: ABE 45400		4	Transport Processes: ABE 45400		4
Unit Operations: ABE 55500		4	Unit Operations: ABE 55500		4
Biological and Food Process Design: ABE 55600		4	Biological and Food Process Design: ABE 55600		4
Process Engineering: ABE 58000		3	Process Engineering: ABE 58000		3
Technical Electives		3	**Technical Electives**		3

Minimum Degree Requirements for Cell & Biomolecular Engineering
Credit Hours Required for Graduation

Present	Total Credit Hours	135	Proposed	Total Credit Hours	135
Courses		*Credit Hours*	*Courses*		*Credit Hours*
Mathematics and Basic Sciences			**Mathematics and Basic Sciences**		
Calculus: MA16500, 16600, 26100, 26500, 26600		18	Calculus: MA16500, 16600, 26100, 26500, 26600		18
Chemistry: CHM 11500, 11600, 25700		12	Chemistry: CHM 11500, 11600, 25700		12
Physics: PHYS 17200, 24100		7	Physics: PHYS 17200, 24100		7
Biological and Food Sciences			**Biology and Life Sciences**		
Biological Sciences: BIOL 22100, 23000, IT 22600		9	Cell Biology: BIOL 23000 or BIOL 23100 or BCHM 30700 Microbiology/Virology/Molecular Biology: IT 22600, 3 credit selective		8
BCHM 22100 or FN 20500		3	Life Science selectives		6
Biological or Food Science Selectives		7	Bioinformatics/Genomics: CNIT 22700		2
Engineering Tools and Skills			**Engineering Tools and Skills**		
ENGR 13100, ENGR 13200, CHE 32000		7	ENGR 13100, ENGR 13200, CHE 32000		7
Professional Development			**Professional Development**		
ABE 29000, 49000		2	ABE 29000, 49000		2
Communication			**Communication**		
English Composition: ENGL 10600		4	English Composition: ENGL 10600		4
Speech: COM 11400		3	Speech: COM 11400		3
Humanities and Social Sciences General Education Must be chosen in accordance with the approved general education list and with the help of a faculty advisor. Of the 18 credit hours, 6 must meet College of Agriculture international understanding requirements, 3 must be an additional communication elective, and 3 must be economics		18	**Humanities and Social Sciences General Education** Must be chosen in accordance with the approved general education list and with the help of a faculty advisor. Of the 18 credit hours, 6 must meet College of Agriculture international understanding requirements, 3 must be an additional communication elective, and 3 must be economics		18
Core Engineering Courses			**Core Engineering Courses**		
Thermodynamics: ABE 20100, 20200, 30100, 30300		13	Thermodynamics: ABE 20100, 20200, 30100, 30300		13
Momentum, Heat and Mass Transfer: CHE 37700, 37800		8	Momentum, Heat and Mass Transfer: CHE 37700, 37800		8
Kinetics and Reaction Engineering: ABE 37000		3	Kinetics and Reaction Engineering: ABE 37000		3
Sensors and Process Control: ABE 460000		3	Sensors and Process Control: ABE 460000		3
Transport Processes: ABE 45400		4	Transport Processes: ABE 45400		4
			Cellular Design Principles: ABE 49500		3
Unit Operations: ABE 55500		4	Unit Operations: ABE 55500		4
Biological and Food Process Design: ABE 55600		4	Biological and Food Process Design: ABE 55600		4

Process Engineering: ABE 58000	**3**	Process Engineering: ABE 58000	**3**
Technical Electives	**3**	**Technical Electives**	**3**

Supporting Documentation – Biological Engineering Plan of Study revisions (FBPE major)

Present   **Proposed - FBPE**

Freshman Year

First Semester

Present	Proposed - FBPE
(4) CHM 11500 General Chemistry I	(4) CHM 11500 General Chemistry I
(4) ENGL 10600 English Composition I	(4) ENGL 10600 English Composition I
(2) ENGR 13100 Transforming Ideas to Innovation I	(2) ENGR 13100 Transforming Ideas to Innovation I
(4) MA 16500 Plane Analytic Geometry and Calculus I	(4) MA 16500 Plane Analytic Geometry and Calculus I
	(3) General Education Elective
14	**17**

Second Semester

Present	Proposed - FBPE
(4) CHM 11600 General Chemistry II	(4) CHM 11600 General Chemistry II
(3) COM 11400 Fundamentals of Speech Communications	(3) COM 11400 Fundamentals of Speech Communications
(4) MA 16600 Plane Analytic Geometry and Calculus II	(2) ENGR 13200 Transforming Ideas to Innovation II
(4) PHYS 17200 Modern Mechanics	(4) MA 16600 Plane Analytic Geometry and Calculus II
(2) ENGR 13200 Transforming Ideas to Innovation II	(4) PHYS 17200 Modern Mechanics
17	**17**

Sophomore Year

Third Semester

Present	Proposed - FBPE
(4) ABE 20100 Thermodynamics of Biological Systems I	(4) ABE 20100 Thermodynamics of Biological Systems I
(4) MA 26100 Multivariate Calculus	(1) ABE 29000 Sophomore Seminar
(4) CHM 25700 Organic Chemistry I	(4) BIOL 11000 Fundamentals of Biology I
(3) BIOL 23000 Biology of the Living Cell	(4) CHM 25700 Organic Chemistry I
(2) IT 22600 Biotechnology Laboratory I	(4) MA 26100 Multivariate Calculus
(1) ABE 29000 Sophomore Seminar	**17**
18	

Fourth Semester

Present	Proposed - FBPE
(3) ABE 20200 Thermodynamics of Biological Systems II	(3) ABE 20200 Thermodynamics of Biological Systems II
(3) BCHM 22100 Analytical Biochemistry OR	(3) CHE 32000 Statistical Modeling
FN 205 Food Science	(3) FN 20500 Food Science
(3) MA 26500 Linear Algebra	(3) MA 26500 Linear Algebra
(3) MA 26600 Ordinary Differential Equations	(3) MA 26600 Ordinary Differential Equations
(3) CHE 32000 Statistical Modeling	(3) General Education Elective
(3) General Education Elective	**18**
18	

Junior Year

Fifth Semester

(3) ABE 30100	Modeling & Computation Tools in Biol. Engr.	(3) ABE 30100 Modeling & Computation Tools in Biol. Engr.
(3) ABE 30300	App of Phys Chemistry to Biol. Processes	(3) ABE 30300 App of Phys Chemistry to Biol. Processes
(4) CHE 37700	Momentum Transfer	(4) CHE 37700 Momentum Transfer
(3) PHYS 24100	Electricity and Optics	(3) PHYS 24100 Electricity and Optics
(3)	General Education Elective	(3) General Education Elective
16		**16**

Sixth Semester

(3) ABE 37000	Biol./Microbial Kinetics & Reaction Engr.	(3) ABE 37000 Biol./Microbial Kinetics & Reaction Engr.
(4) ABE 45400	Transport Processes in Biological and Food Process Systems	(4) ABE 45400 Transport Processes in Biological and Food Process Systems
(4) CHE 37800	Heat and Mass Transfer	(4) BIOL 22100 Microbiology
(4) BIOL 22100	Microbiology	(4) CHE 37800 Heat and Mass Transfer
(3)	General Education Elective	(3) General Education Elective
18		**18**

Senior Year

Seventh Semester

(1) ABE 49000	Professional Practice in Agric. & Biol. Engr	(1) ABE 49000 Professional Practice in Agric. & Biol. Engr
(4) ABE 55500	Biological & Food Processing Unit Operations	(4) ABE 55500 Biological & Food Processing Unit Operations
(4)	Biological or Food Science Elective	(4) Biological or Food Science Elective
(3)	Engineering Elective	(3) Engineering Selective
(6)	General Education Elective	(3) General Education Elective
18		**15**

Eighth Semester

(3) ABE 58000	Process Engineering of Renewable Resources	(3) ABE 46000 Sensors and Process Controls
(4) ABE 55600	Biological and Food Process Design	(4) ABE 55600 Biological and Food Process Design
(3) ABE 46000	Sensors and Process Controls	(3) ABE 58000 Process Engineering of Renewable Resources
(3)	General Education Elective	(4) Biological or Food Science Elective
(3)	Biological or Food Science Elective	(3) General Education Elective
16		**17**

Total   **Total**

135   **135**

Supporting Documentation – Biological Engineering Plan of Study revisions (PPE major)

Present	**Proposed - PPE**

Freshman Year

First Semester

(4) CHM	11500	General Chemistry I	(4) CHM	11500	General Chemistry I
(4) ENGL	10600	English Composition I	(4) ENGL	10600	English Composition I
(2) ENGR	13100	Transforming Ideas to Innovation I	(2) ENGR	13100	Transforming Ideas to Innovation I
(4) MA	16500	Plane Analytic Geometry and Calculus I	(4) MA	16500	Plane Analytic Geometry and Calculus I
			(3)		General Education Elective
14			**17**		

Second Semester

(4) CHM	11600	General Chemistry II	(4) CHM	11600	General Chemistry II
(3) COM	11400	Fundamentals of Speech Communications	(3) COM	11400	Fundamentals of Speech Communications
(4) MA	16600	Plane Analytic Geometry and Calculus II	(2) ENGR	13200	Transforming Ideas to Innovation II
(4) PHYS	17200	Modern Mechanics	(4) MA	16600	Plane Analytic Geometry and Calculus II
(2) ENGR	13200	Transforming Ideas to Innovation II	(4) PHYS	17200	Modern Mechanics
17			**17**		

Sophomore Year

Third Semester

(4) ABE	20100	Thermodynamics of Biological Systems I	(4) ABE	20100	Thermodynamics of Biological Systems I
(4) MA	26100	Multivariate Calculus	(1) ABE	29000	Sophomore Seminar
(4) CHM	25700	Organic Chemistry I	(4) BIOL	11000	Fundamentals of Biology I
(3) BIOL	23000	Biology of the Living Cell	(4) CHM	25700	Organic Chemistry I
(2) IT	22600	Biotechnology Laboratory I	(4) MA	26100	Multivariate Calculus
(1) ABE	29000	Sophomore Seminar	**17**		
18					

Fourth Semester

(3) ABE	20200	Thermodynamics of Biological Systems II	(3) ABE	20200	Thermodynamics of Biological Systems II
(3) BCHM	22100	Analytical Biochemistry **OR**	(3) CHE	32000	Statistical Modeling
		FN 205 Food Science	(3) BCHM	30700	Biochemistry
(3) MA	26500	Linear Algebra	(3) MA	26500	Linear Algebra
(3) MA	26600	Ordinary Differential Equations	(3) MA	26600	Ordinary Differential Equations
(3) CHE	32000	Statistical Modeling	(3)		General Education Elective
(3)		General Education Elective	**18**		
18					

Junior Year

Fifth Semester

(3)	ABE	30100	Modeling & Computation Tools in Biol. Engr.	(3) ABE	30100	Modeling & Computation Tools in Biol. Engr.
(3)	ABE	30300	App of Phys Chemistry to Biol. Processes	(3) ABE	30300	App of Phys Chemistry to Biol. Processes
(4)	CHE	37700	Momentum Transfer	(4) CHE	37700	Momentum Transfer
(3)	PHYS	24100	Electricity and Optics	(3) IPPH	36200	Basic Pharmaceutical I
(3)			General Education Elective	(3) PHYS	24100	Electricity and Optics
16				**16**		

Sixth Semester

(3)	ABE	37000	Biol./Microbial Kinetics & Reaction Engr.	(3) ABE	37000	Biol./Microbial Kinetics & Reaction Engr.
(4)	ABE	45400	Transport Processes in Biological and Food Process Systems	(4) ABE	45400	Transport Processes in Biological and Food Process Systems
(4)	CHE	37800	Heat and Mass Transfer	(4) BIOL	22100	Microbiology
(4)	BIOL	22100	Microbiology	(4) CHE	37800	Heat and Mass Transfer
(3)			General Education Elective	(3) IPPH	36300	Basic Pharmaceutical II
18				**18**		

Senior Year

Seventh Semester

(1)	ABE	49000	Professional Practice in Agric. & Biol. Engr	(1) ABE	49000	Professional Practice in Agric. & Biol. Engr
(4)	ABE	55500	Biological & Food Processing Unit Operations	(4) ABE	55500	Biological & Food Processing Unit Operations
(4)			Biological or Food Science Elective	(3) IPPH	56200	Introduction to Mfg Process
(3)			Engineering Elective	(3)		Engineering Selective
(6)			General Education Elective	(6)		General Education Elective
18				**17**		

Eighth Semester

(3)	ABE	58000	Process Engineering of Renewable Resources	(3) ABE	46000	Sensors and Process Controls
(4)	ABE	55600	Biological and Food Process Design	(4) ABE	55600	Biological and Food Process Design
(3)	ABE	46000	Sensors and Process Controls	(3) ABE	58000	Process Engineering of Renewable Resources
(3)			General Education Elective	(6)		General Education Elective
(3)			Biological or Food Science Elective			
16				**16**		

Total	**Total**
135	**136**

Supporting Documentation - Biological Engineering Plan of Study revisions (CBE major):

Present	**Proposed - CBE**

Freshman Year

First Semester

(4) CHM 11500 General Chemistry I	(4) CHM 11500 General Chemistry I
(4) ENGL 10600 English Composition I	(4) ENGL 10600 English Composition I
(2) ENGR 13100 Transforming Ideas to Innovation I	(2) ENGR 13100 Transforming Ideas to Innovation I
(4) MA 16500 Plane Analytic Geometry and Calculus I	(4) MA 16500 Plane Analytic Geometry and Calculus I
	(3) General Education Elective
14	**17**

Second Semester

(4) CHM 11600 General Chemistry II	(4) CHM 11600 General Chemistry II
(3) COM 11400 Fundamentals of Speech Communications	(3) COM 11400 Fundamentals of Speech Communications
(4) MA 16600 Plane Analytic Geometry and Calculus II	(2) ENGR 13200 Transforming Ideas to Innovation II
(4) PHYS 17200 Modern Mechanics	(4) MA 16600 Plane Analytic Geometry and Calculus II
(2) ENGR 13200 Transforming Ideas to Innovation II	(4) PHYS 17200 Modern Mechanics
17	**17**

Sophomore Year

Third Semester

(4) ABE 20100 Thermodynamics of Biological Systems I	(4) ABE 20100 Thermodynamics of Biological Systems I
(4) MA 26100 Multivariate Calculus	(1) ABE 29000 Sophomore Seminar
(4) CHM 25700 Organic Chemistry I	(3) BIOL 23000 Biology of the Living Cell OR BIOL 23100 OR BCHM 30700
(3) BIOL 23000 Biology of the Living Cell	(4) CHM 25700 Organic Chemistry I
(2) IT 22600 Biotechnology Laboratory I	(2) IT 22600 Biotechnology Laboratory I
(1) ABE 29000 Sophomore Seminar	(4) MA 26100 Multivariate Calculus
18	**18**

Fourth Semester

(3) ABE 20200 Thermodynamics of Biological Systems II	(3) ABE 20200 Thermodynamics of Biological Systems II
(3) BCHM 22100 Analytical Biochemistry **OR** FN 205 Food Science	(3) CHE 32000 Statistical Modeling
(3) MA 26500 Linear Algebra	**(2)** CNIT 22700 Bioinformatics++
(3) MA 26600 Ordinary Differential Equations	(3) MA 26500 Linear Algebra
(3) CHE 32000 Statistical Modeling	(3) MA 26600 Ordinary Differential Equations
(3) General Education Elective	(3) General Education Elective**
18	**17**

Junior Year

Fifth Semester

(3) ABE	30100	Modeling & Computation Tools in Biol. Engr.	(3) ABE 30100	Modeling & Computation Tools in Biol. Engr.
(3) ABE	30300	App of Phys Chemistry to Biol. Processes	(3) ABE 30300	App of Phys Chemistry to Biol. Processes
(4) CHE	37700	Momentum Transfer	(4) CHE 37700	Momentum Transfer
(3) PHYS	24100	Electricity and Optics	(3) PHYS 24100	Electricity and Optics
(3)		General Education Elective	(3)	General Education Elective
16			**16**	

Sixth Semester

(3) ABE	37000	Biol./Microbial Kinetics & Reaction Engr.	(3) ABE 37000	Biol./Microbial Kinetics & Reaction Engr.
(4) ABE	45400	Transport Processes in Biological and Food Process Systems	(4) ABE 45400	Transport Processes in Biological and Food Process Systems
(4) CHE	37800	Heat and Mass Transfer	(4) CHE 37800	Heat and Mass Transfer
(4) BIOL	22100	Microbiology	(3) BIOL 24100	Genetics & Molecular Biology
(3)		General Education Elective	(3) ABE 49500	Cell & Molecular Design Principles
18			**17**	

Senior Year

Seventh Semester

(1) ABE	49000	Professional Practice in Agric. & Biol. Engr	(1) ABE 49000	Professional Practice in Agric. & Biol. Engr
(4) ABE	55500	Biological & Food Processing Unit Operations	(4) ABE 55500	Biological & Food Processing Unit Operations
(4)		Biological or Food Science Elective	(3)	Biology or Science Selective
(3)		Engineering Elective	(3)	Engineering Selective
(6)		General Education Elective	(6)	General Education Elective
18			**17**	

Eighth Semester

(3) ABE	58000	Process Engineering of Renewable Resources	(3) ABE 46000	Sensors and Process Controls
(4) ABE	55600	Biological and Food Process Design	(4) ABE 55600	Biological and Food Process Design
(3) ABE	46000	Sensors and Process Controls	(3) ABE 58000	Process Engineering of Renewable Resources
(3)		General Education Elective	(3)	Biology or Science Selective
			(3)	General Education Elective
(3)		Biological or Food Science Elective	**16**	
16				

Total

135

Total

135

Bernard A. Engel   Date: April 11, 2011
Professor and Head
Agricultural and Biological Engineering Department

Supplemental Material: Course Syllabus for ABE 49500 Cell and Molecular Design Principles

ABE 495 - Cell and Molecular Design Principles

Spring 2012
Instructor: Dr. Jenna Rickus rickus@purdue.edu
Office: MJIS 2029
Phone: 494-1197
Office Hours:

Catalog Description. The design principles underlying mechanisms of cellular functions such as cell architecture, energy storage and conversion, sensing and signaling, communication, time keeping, molecular synthesis, memory, and motility. Emphasis will be placed on the chemical, physical, a*nd mathematical features that determine the performance of the biological device. Topics cover both cellular/biochemical* processes and molecular/genetic circuits. Examples are presented from reverse engineering of natural systems and design of new synthetic systems.

Prerequisites.   MA 265 AND MA 266 AND BIOL 230 (or BIOL 231 or BCHM 307)

Textbook

1. Instructor Compiled Online Textbook in "Scitable" by Nature Education. http://www.nature.com/scitable/group-join/cellular-design-principles-22413806/48811
2. An introduction to systems biology

Additional Readings and References:

3. Rafelski and Marshall "Building the Cell: design principles of cellular architecture". Nature Reviews. 2008.
4. "Design principles of biochemical oscillators." Bovak, Tyson. Nature Reviews Molecular Cell Biology. 2008.

Week 1	**Cell Architecture & Self-Assembly.** Determinants and Regulation of Size and Shape of Cells and Organelles. **Design Principle:** Controlling size and number by molecular rulers, quantal synthesis and dynamic balance. **Example.** Organelle synthesis, turnover, and number
Week 2	**Transport/Diffusion**. Passive versus active intracellular transport. **Design Principles:** Transport limitations/pressures on cell size and impact on energy needs. **Example.** How specialized cells transport over long distances.
Week 3	**Energy Storage and Conversion.** Electrochemical gradients. High energy molecules. **Design principle:** gradients versus discrete storage **Example:** Why are proton gradients universal?
Week 4	**Signaling.** Introduction to signaling. Why multiple levels of regulation? Design advantages, times scales and choices of multiples levels of regulation. Kinase/Phosphatase **Design Principle.** Multi-step Ultra sensitivity. Zero order Ultra sensitivity **Example.** Monitoring Cellular Energy State
Week 5	**Sensing & Signaling.** Introduction to external inputs to cells. **Design Principles.** Amplification in signaling cascades, chemical sources of background noise, adjustable dynamic range (adaption to inputs) in signaling networks. **Example.** Photoreceptors as near perfect photon detectors. Insect detection of signals across miles.
Week 6	**Biological Circuits**. Intro to Transcriptional Networks. Mathematical representation of activators, repressors, multi-input systems.
Week 7	**Biological Circuits.** Network Structure. Network Motifs. Gene and Protein Network Analysis. **Design Principles:** Structural effects on robustness. Connectivity and lethality. **Case Study.** Systematic knockouts in yeast and mycobacteria.

Week 8   **Biological Circuits.** Graphical Analysis of Biochemical Circuit Dynamics. Time domain, frequency domain, phase plane, stability diagrams

Week 9 Gene Circuits. Feed-Forward Loop Network Motif.
                Design Principles. Performance Implications of Negative and Positive Auto regulation Motifs.

Week 10   **Biochemical Oscillators.**   Significance and function of biochemical oscillations in nature and engineered systems.
                Design Principles. General requirements for natural biochemical oscillators. Negative feedback, time delay, nonlinearity, balance of production/consumption time scales.

Week 11   **Time Keeping.** Cellular Clocks and Gene Oscillations.
                Design Principles: inherent oscillations, entrainment
                Example: *period* and *timeless* oscillations with light entrainment in drosophila. Mutants

Week 12   **Biochemical Switches**. Simple Gene Switches, Bistability,
                Design Principle(s). Advantages & disadvantages of simple inducers/repressors versus circuit (bistable switch) on toggle switch performance. Role of stoichiometry / cooperativity in creating a biostable toggle switch
                Example. Genetic toggle switch in E. coli.

Week 13   **Motility.** Mechanisms and Decision making in Cellular locomotion
                Design Principle. Robustness
                Example. Bacterial Chemo taxis

Week 14   **Synthetic Systems.** Synthetics Biology. Standard Registry of Biological Parts, Safety and Ethics
                Design Principles. Abstraction, hierarchy, standardization

Week 15   **Ground Up Cellular Design.**   Approaches to genome synthesis. Alternative codes. Nuclear transfer for cell "boot up".
                Design Principles. Minimum Gene Set.   Watermarking. Identification of synthetic versus native. Engineering Safety Mechanisms.
                Case Study.   First synthetic bacterial genome.

Grading: 25%   Weekly Homework Assignments
                25%   Exam 1
                25%   Exam 2
                25%   Final Exam

Grading Scale:

grade	gpa value	% range
A	4.0	93-100
A-	3.7	90.0-92.9
B+	3.3	87.0-89.9
B	3.0	83.0-86.9
B-	2.7	80.0-82.9
C+	2.3	77.0-79.9
C	2.0	73.0-76.9
C-	1.7	70.0-72.9
D+	1.3	67.0-69.9
D	1.0	63.0-66.9
D-	0.7	60.0-62.9
F	0.0	<60.0