Development of an undergraduate bioengineering curriculum that mirrors the breadth of the field

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Abstract—Temple University's Bioengineering undergraduate program was launched in Fall 2013 and initially comprised a unified bioengineering "overview" curriculum. The department has been hiring faculty from a wide variety of bioengineering specialties and the difficulty came with the development of the curriculum that reflected this diversity. The bioengineering curriculum was modified using the backward course design concept [1] by looking at the contents of the proposed senior capstone classes and redesigning the seven course pathways to ensure that the students will have the appropriate foundational knowledge needed to succeed in their chosen capstone course. The pathways have some flexibility in case a student wished to move between particular pathways, but the choice of pathway has to be made fairly early in the student's plan of study.

***Index Terms*—Bioengineering, curriculum development, undergraduate level**

I. Introduction

THERE has been much discussion of the need for people to pursue STEM education degrees and remain in STEM fields in order to contribute to the competitive standing of the US in the current technology-driven world. [2, 3] Students that enter engineering today want to study in areas that "make a difference to society." [4] Bioengineering, as the relative newcomer in the engineering education world, has a distinct advantage of attracting interest from undergraduate students and their families due to recent media reports of good job prospects [5, 6] and the direct links between this field and improvements to global health. This has led to the creation of several undergraduate bioengineering programs in the region and an increase in the numbers of students declaring bioengineering as their major.

A disadvantage to studying bioengineering at the undergraduate level, as compared to more traditional engineering fields, such as mechanical or electrical engineering, is the incredible breath of the field. Most traditional engineering tracks have fairly set common curricula in the first two of years of a four year degree, and then may offer some options for greater specificity at the upper levels. An on-line review of bioengineering undergraduate programs in the US shows that most programs focus on a few specific areas of concentration. This allows for a reduction in the total number of bioengineering-specific courses needed and can initially follow the general common curricula model of other engineering disciplines. For a program with a greater number of areas of concentration, this curriculum set up might be more difficult.

The purpose of this paper is to provide details of the curriculum development of Temple University's (TU) Bioengineering program as an example to other programs that may wish to include a broader spectrum of areas within their undergraduate bioengineering curricula.

II. Curriculum Needs

The original (Fall 2013) approved curriculum for our Bioengineering (BIOE) department had to meet the College of Engineering's mandated minimum of 124 semester hours (s.h.). In addition, the number of credit hours was defined by ABET requirements for engineering programs. ABET suggests a minimum of 31 credits in foundation math and science and a minimum of 46.5 credits in engineering science and design for a curriculum of 124 s.h. As seen in Table I, our initial curriculum exceeded the ABET requirements with 34 credits with foundational math (Calculus 1, 2, and 3; Differential Equations; and Linear Algebra) and science, and 50 engineering credits. The course breakdown for our initial curriculum included mandatory foundational math and science, required and elective engineering courses, technical electives, and Temple's university wide general education (GenEd) courses (Table I). Technical electives were student-selected math, science, or engineering courses that will help them in upper level bioengineering courses.

Table I
Previous general curriculum requirements

Course type	Semester hours
Foundation Mathematics	18
Foundational Science	16
Required and elective Engineering	50
Technical Electives	15
General Education	25
Minimum number of credit hours	**124**

A. Capstone Conundrum

As part of the engineering-required courses students will have to take two senior capstone courses in addition to a year of senior design. These capstone courses, which will be chosen by the student, could be taken in a variety of areas, such as biomaterials, tissue engineering, or biomechanics. The students will prepare for these senior capstone courses by selection of bioengineering and technical electives during their course of study at TU. However, the pre-requisites for these capstone courses varied and careful selections of technical and

bioengineering electives were required so make sure that the students will be able to select their desired capstone courses. This will require that the student decide early in their undergraduate career, which capstone courses they will take. Then they will have to plan their course of study with the end in mind: the burden of course selection was on the students with advising from the department faculty.

B. The Biology Issue

As a bioengineering program, we agreed that in-depth biology education is required. A mandatory biology course was to be part of the required foundational science courses and should be taken during the first semester of the student's undergraduate careers.

Unfortunately, the originally approved course turned out to be too low level for students getting a bioengineering degree and we decided to change to a more rigorous course.

C. Transfer Students

For our first year, prior to us offering any BIOE courses, we had three actual applicants to the bioengineering program. We then got approximately 30 freshmen that were accepted into the College of Engineering and switched into BIOE that first semester. We also had 18 students that transferred over to our program as sophomores. These transfer students were concerned that they were "behind" in the program since they had not taken the required biology course during their freshmen year. In addition, the first required BIOE course, set for the fall of the sophomore year, had a pre-requisite of biology. These students needed to get waivers to take the first BIOE course and stay on track.

Due to the number of waiver requests, the administration of the College of Engineering requested that we reduce the number of needed waivers for our new transfer students. In addition, we were asked to change our first year curriculum to have a "common first year" with the other departments within the college, which included an Introduction to Engineering course in the fall and a department-specific course in the spring. Finally, we were asked to reduce the number of required courses to allow more flexibility in schedules for the students. To this end we were asked to add two "free electives" for a total of 6 credits without increasing the minimum required credit hours of 124 s.h.

III. PATHWAY DEVELOPMENT

During the past year, the bioengineering curriculum was modified using the backward course design concept [1] by looking at the contents of the proposed senior capstone classes and redesigning seven course pathways to ensure that the students will have the appropriate foundational knowledge needed to succeed in their chosen capstone course. With consideration of these many factors, the redesign of our curriculum was necessary. To accommodate the varied interests and academic backgrounds of our incoming students, the pathways have to have some flexibility. However; the choice of pathway has to be made fairly early in the student's plan of study to keep students on track to graduate within a reasonable timeframe.

A. Pathways

We introduced a number of pathways within BIOE that will demonstrate the breadth of the field while allowing the students to focus on different areas within bioengineering. Each pathway will culminate in a capstone course during the senior year in either the 7th or 8th semester of study in a four-year curriculum. The proposed pathways for students to choose from are as follows:

- Biomaterials
- Biomechanics
- Bioimaging
- Bioinstrumentation
- Neuroengineering
- Pre-med
- Tissue Engineering

Each of these pathways has an associated senior capstone course and a selection of technical and bioengineering electives. These pathways were developed into new 8-semester grid courses of study (see Appendix).

We had many requests from students who wish to enter medical school after getting an undergraduate BIOE degree at TU. Bioengineering is an excellent avenue to obtaining all of the pre-med requirements while earning an engineering degree. We developed this pathway so that it will include all of the pre-med course requirements and will also lead to one of the senior capstone courses. In this case, the senior capstone was Tissue Engineering. Pre-med and Tissue Engineering pathways are very similar with only two additional required pre-med courses (Introduction to Sociology and Introduction to Psychology) added.

In addition, we grouped the pathways into those that have a cellular/chemistry basis (Tissue Engineering, Biomaterials, Neuro-engineering, and Pre-med) and those that do not. This potentially allows for students to shift from one pathway to another within each grouping.

B. Biology

Moving the biology course to the second year enables transfer students to get on track more easily, especially if they are moving from another engineering discipline that had not previously required biology. In addition, we redesigned our first BIOE course to better showcase the various pathways and include discussions of associated didactic coursework and potential career options. We removed the biology pre-requisite and moved this introductory BIOE course into the second semester (spring freshmen year). This solved the "common first year" issue and offered a course that introduced the pathways early in the careers of students so that they will be able to choose a pathway with greater knowledge about the learning outcomes within each field of BIOE.

In addition, moving the biology course to the 4th semester (spring sophomore year), allows the students to choose from five possible biology courses that could meet the foundational biology requirement. These new choices included the required "pre-med" biology courses, honors biology classes, or general cellular biology. The selection of possible courses also helps

reduce the burden on the biology department for providing extra sections if all bioengineers were to take a single class.

C. Free Electives

In order include greater flexibility in the curriculum and to be more inclusive of students, especially transfer students, who may wish to declare bioengineering as their major course of study, we removed two required courses from the program and replaced them with "free electives." In essence, these "free electives" could be any course offered by TU, but require approval by the department.

The courses removed from the required course list were linear algebra (3 s.h.) and the second BIOE senior capstone (3 s.h.). With the inclusion of "free electives" into the curriculum and removal of additional requirements, we hope students will feel that they can choose Bioengineering if they are undecided during their freshman year or transfer from other departments and still graduate within a reasonable time frame.

The removal of linear algebra will reduce the number of required foundation math and science credits from 34 to 31, which meets the minimum number of foundation of math and science credits required for accreditation purposes as specified by ABET. The removal of second capstone will reduce the number of required engineering science and design credits from 50 to 47, which is still above the minimum number of engineering science and design credits required for accreditation purposes as specified by ABET (Table II). However, certain pathways, like tissue engineering, will require that these "free electives" be approved "strongly recommended" engineering courses in order to meet ABET requirements for engineering science and design credits earned. Students are advised of these requirements depending on the pathway they wish to pursue.

TABLE II

New curriculum requirements

Course type	Semester hours
Foundation Mathematics	15
Foundational Science	16
Required and elective Engineering	47
Technical Electives	15
General Education	25
Free Electives	6
Minimum number of credit hours	**124**

IV. DISCUSSION

The pathways offered in the TU BIOE curriculum focus on current research interests of the faculty in our department. This ensures that we have the expertise to cover each of the BIOE courses that we have selected for each of the seven pathways

We feel that the recent modifications to the current program will make the bioengineering curriculum more accessible to students transferring in from other engineering disciplines and other colleges within Temple, as well as, transfer engineering students from other universities. Arranging our curriculum to more closely match those of other engineering departments in the first year and making the proposed changes will more easily allow students to transfer into our program with little loss of course time during their first two years of study. As bioengineering is such a broad field, no general course of study will really ground students in any area that will be useful in future careers or further study. The introduction of well-defined pathways will enable students to plan more effectively their courses of study needed to obtain their degree and help inform them of possible career choices available to them after graduation.

The reduction in the number of required courses means that most students that choose to transfer into our program will be able to complete the bioengineering program in a reasonable amount of time. It also will allow students more flexibility in choosing a course of study that is more tailored to their interests, which will increase their depth of knowledge, or allow them to explore different areas that will increase their breath of knowledge.

ACKNOWLEDGMENT

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REFERENCES

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[5] CNN Money, vol. 2014, 2012.

[6] Bureau of Labor Statistics, vol. 2014, 2014.

Ruth S. Ochia received the B.S. degree in biomedical engineering from The Johns Hopkins University, Baltimore, MD, in 1992 and the Ph.D. degree in bioengineering from the University of Washington, Seattle, WA, in 2000.

From 2000 to 2002, she was a Post-doctoral Fellow in the Center of Locomotion Studies, at The Pennsylvania State University, State College, PA. From 2002 to 2006, she was a Post-doctoral Fellow and then Assistant Professor at Rush University Medical Center, Chicago, IL. From 2006 to 2009, she was a Senior Associate with Exponent, Inc. From 2009 to 2013, she was principal of RSO Consulting, LLC, and taught as an Adjunct Professor at Widener University, Chester, PA. Since 2013, she has been an Associate Professor with the Bioengineering Department, Temple University, Philadelphia, PA. Her research interests have included biomechanics, primarily focusing on spine-related injuries and degeneration. Currently, her interests are in engineering education, curriculum development and assessment.

Dr. Ochia is a licensed professional engineer in the state of Pennsylvania. She is a member of the Orthopaedic Research Society (ORS), American Society of Mechanical Engineers (ASME), and Biomedical Engineering Society (BMES).

V. APPENDIX: 8-SEMESTER GRIDS FOR BS IN BIOENGINEERING

Pre-med

FALL						SPRING					
1st SEMESTER			**S.H.**	**Sem**	**Grd**	**2nd SEMESTER**			**S.H.**	**Sem**	**Grd**
MATH	1041	Calculus I	4			MATH	1042	Calculus II	4		
CHEM	1031/33	Chemistry I & Lab	4			CHEM	1032/34	Chemistry II w/ Lab	4		
ENGR	1101	Introduction to Engineering	3			PHYS	1061	Elementary Classical Physics I w/Lab	4		
ENGL	**0802**	**Analytical Reading & Writing**	**4**			BIOL	1111	Biology 1 w/ lab	4		
		SEMESTER TOTAL	**15**					**SEMESTER TOTAL**	**16**		
3rd SEMESTER						**4th SEMESTER**					
PHYS	1062	Elem. Class. Physics II w/Lab	4			MATH	3041	Differential Equations	3		
CHEM	2201/03	Organic Chem I w/Lab	4			ENGR	3571	Thermodynamics	3		
BIOE	2001	Principles of Bioengineering	2			BIOE	2101	Eng. Principles of Physiological Systems w/Lab	3		
ENGR	2196	Technical Communications	3			CHEM	2202/04	Organic Chem II w/Lab	4		
MATH	2043	Calculus III	4			**IH**	**0851**	**Mosaic 1**	**3**		
		SEMESTER TOTAL	**17**					**SEMESTER TOTAL**	**16**		
5th SEMESTER						**6th SEMESTER**					
BIOE	3101	BIOE Lab #1: Bioelectricity	3			BIOE	3102	Bioengineering Lab #2: Biomaterials	3		
BIOL	2112	Biology II w/ lab	4			BIOE	1301	Principles of Macromolecular Science	3		
IH	**0852**	**Mosaic II**	**3**			PSY	1001	Intro to Psychology	3		
BIOE	3001	Research Design and Methods	2			ENGR	4169	Engineering Seminar	1		
BIOE	3201	Biomedical Instrumentation	2			CHEM	4401	Biochemistry 1	3		
SOC	1176	Intro to Sociology	3			BIOE	4311	The Entrepreneurial BioEngineer	2		
		SEMESTER TOTAL	**17**					**SEMESTER TOTAL**	**15**		
7th SEMESTER						**8th SEMESTER**					
BIOE	4101	Bioengineering Lab 3: Biomechanics	3			ENGR	4296	Engineering Design Project II	3		
ENGR	4196	Engineering Design Project 1	1			BIOE	3511	Interactions of Biomat'ls with living systems w/ lab	3		
BIOE	4461	Capstone: Principles of Tissue and Regenerative medicine	3			**GenED**	**08xx**	**American Society**	**3**		
GenEd	**08xx**	**World Society**	**3**			BIOE		Bioe elective 3	4		
GenEd	**08xx**	**The Arts - GA**	**3**			**GenEd**	**08xx**	**Race & Diversity**	**3**		
GenEd	**08xx**	**Human Behavior**	**3**								
		SEMESTER TOTAL	**16**					**SEMESTER TOTAL**	**16**		
								TOTAL CREDITS	128		

Pre-med Pathway with suggested courses placed semester by semester. This pathway requires the student to take more than the minimum 124 credits due to the extra courses required for entry to medical school. All pre-med required courses are to be completed prior to taking the MCAT, which is typically taken in the summer between the 6th and 7th semesters of study. Courses in red are required BIOE classes, green are bioengineering electives, blue are technical electives, orange are free electives, and bold are general education courses.

Biomaterials

FALL						SPRING					
1st SEMESTER			**S.H.**	**Sem**	**Grd**	**2nd SEMESTER**			**S.H.**	**Sem**	**Grd**
MATH	1041	Calculus I	4			MATH	1042	Calculus II	4		
CHEM	1031 or 1035/33	Chemistry 1 or Chem for engineers & Lab	4			**IH**	**0851**	**Mosaic I**	3		
ENGR	1101	Introduction to Engineering	3			PHYS	1061	Elementary Classical Physics I w/Lab	4		
ENGL	**0802**	**Analytical Reading & Writing**	**4**			BIOE	2001	Principles of Bioengineering	2		
						CHEM	1032/34	Chem 2 w/ lab or BIOE Equivalent	**4**		
		SEMESTER TOTAL	**15**					**SEMESTER TOTAL**	**17**		
3rd SEMESTER						**4th SEMESTER**					
PHYS	1062	Elem. Class. Physics II w/Lab	4			MATH	3041	Differential Equations	3		
CHEM	2201/03	Organic Chemistry 1 w/ Lab or BIOE equivalent	4			ENGR	3571	Thermodynamics	3		
BIOL	2112/2912	Biology 2 w/ lab or BIOE equivalent	4			BIOE	2101	Eng. Principles of Physiological Systems w/Lab	3		
MATH	2043	Calculus III	4			ENGR	2196	Technical Communications	3		
						CHEM	2202/04	Organic Chemistry 2 w/ lab or BIOE equivalent	4		
		SEMESTER TOTAL	**16**					**SEMESTER TOTAL**	**16**		
5th SEMESTER						**6th SEMESTER**					
BIOE	3001	Research Design and Methods	2			BIOE	3102	Bioengineering Lab 2: Biomaterials	3		
BIOE	3101	BIOE Lab #1: Bioelectrical Eng	3			**GenEd**	**08xx**	**Human Behavior**	**3**		
IH	**0852**	**Mosaic II**	**3**			**GenEd**	**08xx**	**Race & Diversity**	**3**		
BIOE	1301	Principles of Macromolecular Science	3			ENGR	4169	Engineering Seminar	1		
BIOE	3201	Biomedical Instrumentation	2			BIOE	4311	The Entrepreneurial BioEngineer	2		
		Free elective	3			BIOE	2312	Mechanics for BIOE 1	4		
		SEMESTER TOTAL	**16**					**SEMESTER TOTAL**	**16**		
7th SEMESTER						**8th SEMESTER**					
BIOE	4101	Bioengineering Lab 3: Biomechanics	3			ENGR	4296	Engineering Design Project II	3		
ENGR	4196	Engineering Design Project 1	1			BIOE	3511	Interactions of Biomaterials w/ Living systems w/lab	3		
		Free elective	3			**GenED**	**08xx**	**American Society**	**3**		
GenEd	**08xx**	**World Society**	**3**			BIOE	4301	Capstone: Biomaterials	3		
		Tech Elective	3			**GenEd**	**08xx**	**The Arts - GA**	**3**		
		SEMESTER TOTAL	**13**					**SEMESTER TOTAL**	**15**		
								TOTAL CREDITS	124		

Biomaterials Pathway with suggested courses placed semester by semester. Courses in red are required BIOE classes, green are bioengineering electives, blue are technical electives, orange are free electives, and bold are general education courses.

Biomechanics

FALL						SPRING					
1st SEMESTER			**S.H.**	**Sem**	**Grd**	**2nd SEMESTER**			**S.H.**	**Sem**	**Grd**
MATH	1041	Calculus I	4			MATH	1042	Calculus II	4		
CHEM	1031 or 1035/33	Chemistry 1 or Chem for engineers & Lab	4			**IH**	**0851**	**Mosaic I**	3		
ENGR	1101	Introduction to Engineering	3			PHYS	1061	Elementary Classical Physics I w/Lab	4		
ENGL	**0802**	**Analytical Reading & Writing**	**4**			BIOE	2001	Principles of Bioengineering	2		
						ENGR	1117	Engineering Graphics	**2**		
		SEMESTER TOTAL	**15**					**SEMESTER TOTAL**	**15**		
3rd SEMESTER						**4th SEMESTER**					
PHYS	1062	Elem. Class. Physics II w/Lab	4			MATH	3041	Differential Equations	3		
		Tech Elective	4			ENGR	3571	Thermodynamics	3		
ENGR	2196	Technical Communications	3			BIOE	2101	Eng. Principles of Physiological Systems w/Lab	3		
MATH	2043	Calculus III	4			BIOL	1012	General Biology 2 w/ lab or BIOE equivalent	4		
						BIOE	2312	Mechanics for BIOE 1	4		
		SEMESTER TOTAL	**15**					**SEMESTER TOTAL**	**17**		
5th SEMESTER						**6th SEMESTER**					
BIOE	3001	Research Design and Methods	2			BIOE	3102	Bioengineering Lab 2: Biomaterials	3		
BIOE	3101	BIOE Lab #1: Bioelectrical Eng	3			**GenEd**	**08xx**	**Human Behavior**	**3**		
IH	**0852**	**Mosaic II**	**3**			**GenEd**	**08xx**	**Race & Diversity**	**3**		
BIOE	3312	Mechanics for BIOE 2	4			ENGR	4169	Engineering Seminar	1		
BIOE	3201	Biomedical Instrumentation	2			ENGR	3033	The Entrepreneurial Engineer	3		
		Free elective	3			ENGR	3117	Computer Aided Design	3		
		SEMESTER TOTAL	**17**					**SEMESTER TOTAL**	**16**		
7th SEMESTER						**8th SEMESTER**					
BIOE	4101	Bioengineering Lab 3: Biomechanics	3			ENGR	4296	Engineering Design Project II	3		
ENGR	4196	Engineering Design Project 1	1			BIOE		Bioe elective #3	4		
BIOE	4441	Capstone: Biomechanics	3			**GenED**	**08xx**	**American Society**	**3**		
GenEd	**08xx**	**World Society**	**3**					Free elective	3		
ENGR	3553	Mechanics of Fluids	3			**GenEd**	**08xx**	**The Arts - GA**	**3**		
		SEMESTER TOTAL	**13**					**SEMESTER TOTAL**	**16**		
								TOTAL CREDITS	124		

Biomechanics Pathway with suggested courses placed semester by semester. Courses in red are required BIOE classes, green are bioengineering electives, blue are technical electives, orange are free electives, and bold are general education courses.

Bioinstrumentation

FALL						SPRING					
1st SEMESTER			**S.H.**	**Sem**	**Grd**	**2nd SEMESTER**			**S.H.**	**Sem**	**Grd**
MATH	1041	Calculus I	4			MATH	1042	Calculus II	4		
CHEM	1031 or 1035/33	Chemistry 1 or Chem for engineers & Lab	4			**IH**	**0851**	**Mosaic I**	3		
ENGR	1101	Introduction to Engineering	3			PHYS	1061	Elementary Classical Physics I w/Lab	4		
ENGL	**0802**	**Analytical Reading & Writing**	**4**			BIOE	2001	Principles of Bioengineering	2		
						CIS	1057	Computer Programming in C	**4**		
		SEMESTER TOTAL	**15**					**SEMESTER TOTAL**	**17**		
3rd SEMESTER						**4th SEMESTER**					
PHYS	1062	Elem. Class. Physics II w/Lab	4			MATH	3041	Differential Equations	3		
ECE	2112/13	Electrical Devices and Systems 1 w/ lab	4			ENGR	3571	Thermodynamics	3		
ENGR	2196	Technical Communications	3			BIOE	2101	Eng. Principles of Physiological Systems w/Lab	3		
MATH	2043	Calculus III	4			BIOL	1012	General Biology 2 w/ lab or BIOE equivalent	4		
								Free elective	3		
		SEMESTER TOTAL	**15**					**SEMESTER TOTAL**	**16**		
5th SEMESTER						**6th SEMESTER**					
BIOE	3001	Research Design and Methods	2			BIOE	3102	Bioengineering Lab 2: Biomaterials	3		
BIOE	3101	BIOE Lab #1: Bioelectrical Eng	3			**GenEd**	**08xx**	**Human Behavior**	**3**		
IH	**0852**	**Mosaic II**	**3**			**GenEd**	**08xx**	**Race & Diversity**	**3**		
BIOE	3301	Biomedical Signals and Systems	3			ENGR	4169	Engineering Seminar	1		
BIOE	3201	Biomedical Instrumentation	2			BIOE	4311	The Entrepreneurial BioEngineer	2		
ECE	3512	Signals: Continuous and Discrete	4			ECE	3412/13	Classical Control Systems w/ Lab	4		
		SEMESTER TOTAL	**17**					**SEMESTER TOTAL**	**16**		
7th SEMESTER						**8th SEMESTER**					
BIOE	4101	Bioengineering Lab 3: Biomechanics	3			ENGR	4296	Engineering Design Project II	3		
ENGR	4196	Engineering Design Project 1	1			BIOE		Bioe elective #3	3		
BIOE		Capstone Elective #1	3			**GenED**	**08xx**	**American Society**	**3**		
GenEd	**08xx**	**World Society**	**3**					Free elective	3		
BIOE		BIOE elective #2	3			**GenEd**	**08xx**	**The Arts - GA**	**3**		
		SEMESTER TOTAL	**13**					**SEMESTER TOTAL**	**15**		
								TOTAL CREDITS	124		

Bioinstrumentation Pathway with suggested courses placed semester by semester. Courses in red are required BIOE classes, green are bioengineering electives, blue are technical electives, orange are free electives, and bold are general education courses.

Bioimaging

FALL						SPRING					
1st SEMESTER			**S.H.**	**Sem**	**Grd**	**2nd SEMESTER**			**S.H.**	**Sem**	**Grd**
MATH	1041	Calculus I	4			MATH	1042	Calculus II	4		
CHEM	1031 or 1035/33	Chemistry 1 or Chem for engineers & Lab	4			**IH**	**0851**	**Mosaic I**	3		
ENGR	1101	Introduction to Engineering	3			PHYS	1061	Elementary Classical Physics I w/Lab	4		
ENGL	**0802**	**Analytical Reading & Writing**	**4**			BIOE	2001	Principles of Bioengineering	2		
						CIS	1057	Computer Programming in C	**4**		
		SEMESTER TOTAL	**15**					**SEMESTER TOTAL**	**17**		
3rd SEMESTER						**4th SEMESTER**					
PHYS	1062	Elem. Class. Physics II w/Lab	4			MATH	3041	Differential Equations	3		
ECE	2112/13	Electrical Devices and Systems 1 w/ lab	4			ENGR	3571	Thermodynamics	3		
ENGR	2196	Technical Communications	3			BIOE	2101	Eng. Principles of Physiological Systems w/Lab	3		
MATH	2043	Calculus III	4			BIOL	1012	General Biology 2 w/ lab or BIOE equivalent	4		
								Free elective	3		
		SEMESTER TOTAL	**15**					**SEMESTER TOTAL**	**16**		
5th SEMESTER						**6th SEMESTER**					
BIOE	3001	Research Design and Methods	2			BIOE	3102	Bioengineering Lab 2: Biomaterials	3		
BIOE	3101	BIOE Lab #1: Bioelectrical Eng	3			**GenEd**	**08xx**	**Human Behavior**	**3**		
IH	**0852**	**Mosaic II**	**3**			**GenEd**	**08xx**	**Race & Diversity**	**3**		
BIOE	3301	Biomedical Signals and Systems	3			ENGR	4169	Engineering Seminar	1		
BIOE	3201	Biomedical Instrumentation	2			BIOE	4311	The Entrepreneurial BioEngineer	2		
ECE	3512	Signals: Continuous and Discrete	4			ECE	XXXX	Image Processing	4		
		SEMESTER TOTAL	**17**					**SEMESTER TOTAL**	**16**		
7th SEMESTER						**8th SEMESTER**					
BIOE	4101	Bioengineering Lab 3: Biomechanics	3			ENGR	4296	Engineering Design Project II	3		
ENGR	4196	Engineering Design Project 1	1			BIOE		Bioe elective #3	3		
		Free elective	3			**GenED**	**08xx**	**American Society**	**3**		
GenEd	**08xx**	**World Society**	**3**			BIOE	4451	Capstone Elective: Biomedical Imaging	3		
BIOE	4333	Applied Biospectroscopy	3			**GenEd**	**08xx**	**The Arts - GA**	**3**		
		SEMESTER TOTAL	**13**					**SEMESTER TOTAL**	**15**		
								TOTAL CREDITS	124		

Bioimaging Pathway with suggested courses placed semester by semester. Courses in red are required BIOE classes, green are bioengineering electives, blue are technical electives, orange are free electives, and bold are general education courses.

Neuro-Engineering

FALL						SPRING					
1st SEMESTER			**S.H.**	**Sem**	**Grd**	**2nd SEMESTER**			**S.H.**	**Sem**	**Grd**
MATH	1041	Calculus I	4			MATH	1042	Calculus II	4		
CHEM	1031 or 1035/33	Chemistry 1 or Chem for engineers & Lab	4			**IH**	**0851**	**Mosaic I**	3		
ENGR	1101	Introduction to Engineering	3			PHYS	1061	Elementary Classical Physics I w/Lab	4		
ENGL	**0802**	**Analytical Reading & Writing**	**4**			BIOE	2001	Principles of Bioengineering	2		
						CHEM	1032/34	Chem 2 w/ lab or BIOE Equivalent	**4**		
		SEMESTER TOTAL	**15**					**SEMESTER TOTAL**	**17**		
3rd SEMESTER						**4th SEMESTER**					
PHYS	1062	Elem. Class. Physics II w/Lab	4			MATH	3041	Differential Equations	3		
CHEM	2201/03	Organic Chemistry 1 w/ Lab or BIOE equivalent	4			ENGR	3571	Thermodynamics	3		
BIOL	2112/2912	Biology 2 w/ lab or BIOE equivalvent	4			BIOE	2101	Eng. Principles of Physiological Systems w/Lab	3		
MATH	2043	Calculus III	4			ENGR	2196	Technical Communications	3		
						BIOL	1111/1911	Biology 1 w/ lab or BIOE equivalent	4		
		SEMESTER TOTAL	**16**					**SEMESTER TOTAL**	**16**		
5th SEMESTER						**6th SEMESTER**					
BIOE	3001	Research Design and Methods	2			BIOE	3102	Bioengineering Lab 2: Biomaterials	3		
BIOE	3101	BIOE Lab #1: Bioelectrical Eng	3			**GenEd**	**08xx**	**Human Behavior**	**3**		
IH	**0852**	**Mosaic II**	**3**			**GenEd**	**08xx**	**Race & Diversity**	**3**		
BIOL	3352	Systems Neuroscience or BIOE equivalent	3			ENGR	4169	Engineering Seminar	1		
BIOE	3201	Biomedical Instrumentation	2			BIOE	3301	Biomedical Signals and Systems	3		
		Free elective	3			BIOE	3725	Cell Biology for Engineers	3		
		SEMESTER TOTAL	**16**					**SEMESTER TOTAL**	**16**		
7th SEMESTER						**8th SEMESTER**					
BIOE	4101	Bioengineering Lab 3: Biomechanics	3			ENGR	4296	Engineering Design Project II	3		
ENGR	4196	Engineering Design Project 1	1			**BIOE**		BIOE Elective #3	**3**		
BIOE	4461	Capstone: Principles of Tissue and Regenerateive Medicine	3			**GenED**	**08xx**	**American Society**	**3**		
GenEd	**08xx**	**World Society**	**3**					Free elective	3		
BIOL	3354	Neuro Basis of Animal Behavior or BIOE equivalent	3			**GenEd**	**08xx**	**The Arts - GA**	**3**		
BIOE	4311	The Entrepreneurial BioEngineer	2								
		SEMESTER TOTAL	**15**					**SEMESTER TOTAL**	**15**		
								TOTAL CREDITS	126		

Neuro-engineering Pathway with suggested courses placed semester by semester. Courses in red are required BIOE classes, green are bioengineering electives, blue are technical electives, orange are free electives, and bold are general education courses. Note: This pathway requires additional courses outside of degree requirements and one of the free electives needs to be an approved engineering course.

Tissue Engineering

FALL						SPRING					
1st SEMESTER			**S.H.**	**Sem**	**Grd**	**2nd SEMESTER**			**S.H.**	**Sem**	**Grd**
MATH	1041	Calculus I	4			MATH	1042	Calculus II	4		
CHEM	1031 or 1035/33	Chemistry 1 or Chem for engineers & Lab	4			**IH**	**0851**	**Mosaic I**	3		
ENGR	1101	Introduction to Engineering	3			PHYS	1061	Elementary Classical Physics I w/Lab	4		
ENGL	**0802**	**Analytical Reading & Writing**	**4**			BIOE	2001	Principles of Bioengineering	2		
						CHEM	1032/34	Chem 2 w/ lab or BIOE Equivalent	**4**		
		SEMESTER TOTAL	**15**					**SEMESTER TOTAL**	**17**		
3rd SEMESTER						**4th SEMESTER**					
PHYS	1062	Elem. Class. Physics II w/Lab	4			MATH	3041	Differential Equations	3		
CHEM	2201/03	Organic Chemistry 1 w/ Lab or BIOE equivalent	4			ENGR	3571	Thermodynamics	3		
ENGR	2196	Technical Communications	3			BIOE	2101	Eng. Principles of Physiological Systems w/Lab	3		
MATH	2043	Calculus III	4			BIOL	1111/1911	Biology 1 w/ lab or BIOE equivalent	4		
						CHEM	2202/04	Organic Chemistry 2 w/ lab or BIOE equivalent	4		
		SEMESTER TOTAL	**15**					**SEMESTER TOTAL**	**17**		
5th SEMESTER						**6th SEMESTER**					
BIOE	3001	Research Design and Methods	2			BIOE	3102	Bioengineering Lab 2: Biomaterials	3		
BIOE	3101	BIOE Lab #1: Bioelectrical Eng	3			**GenEd**	**08xx**	**Human Behavior**	**3**		
IH	**0852**	**Mosaic II**	**3**			**GenEd**	**08xx**	**Race & Diversity**	**3**		
BIOL	2112/2912	Biology 2 w/ lab or BIOE equivalvent	4			ENGR	4169	Engineering Seminar	1		
BIOE	3201	Biomedical Instrumentation	2			BIOE	3511	Interactions of Biomaterials w/ Living systems w/lab	3		
		Free elective	3			CHEM	4401	Biochemistry 1 or BIOE equivalent	3		
		SEMESTER TOTAL	**17**					**SEMESTER TOTAL**	**16**		
7th SEMESTER						**8th SEMESTER**					
BIOE	4101	Bioengineering Lab 3: Biomechanics	3			ENGR	4296	Engineering Design Project II	3		
ENGR	4196	Engineering Design Project 1	1			BIOE		BIOE Elective #3	3		
BIOE	4461	Capstone: Principles of Tissue and Regenerateive Medicine	3			**GenED**	**08xx**	**American Society**	**3**		
GenEd	**08xx**	**World Society**	**3**					Free elective	3		
BIOE	4311	The Entrepreneurial BioEngineer	2			**GenEd**	**08xx**	**The Arts - GA**	**3**		
		SEMESTER TOTAL	**12**					**SEMESTER TOTAL**	**15**		
								TOTAL CREDITS	124		

Tissue Engineering Pathway with suggested courses placed semester by semester. Courses in red are required BIOE classes, green are bioengineering electives, blue are technical electives, orange are free electives, and bold are general education courses. Note: Free electives need to be approved engineering electives.