CONCENTRATIONS WITHIN THE BIOLOGICAL ENGINEERING PROGRAM

A concentration is a graduation requirement and students are required to complete one of the three Biological Engineering Concentrations: ***Biomedical Engineering, Bioprocess Engineering, Bioenvironmental Engineering***. Concentrations are intended to be used as an introduction to areas in biological engineering that relate to individual interests and preparation for careers or graduate study. They are also intended to help students select electives while planning an individual curriculum. You are encouraged to work closely with your faculty advisor to select concentration electives that meet your academic objectives.

BIOMEDICAL ENGINEERING CONCENTRATION

Although biological engineering is broader than any one application area such as biomedical engineering, human system applications obviously is a critical part of the biological engineering program. Many of the biological engineering courses, especially at the junior and senior level, have been designed with human systems as the major emphasis. Thus, the *core biological engineering courses* in molecular and cellular biological engineering, bio-thermodynamics, bio-fluid mechanics and bio-transport all include biomedical applications.

The objective of the concentration in biomedical engineering is to relate the broader biological engineering program to the individual's interest in preparing for an industrial career or graduate study in areas related to human medicine, veterinary medicine and dentistry. The concentration should guide the individual in choosing elective subjects that they will use in their life after graduation.

The table below is a list of elective courses in biomedical engineering (beyond the *core* discussed earlier) grouped into topical areas of upper level subject matter and applications.

To further enhance the concentration and the curriculum in general, undergraduate research or independent study is encouraged. Such work could be with faculty members within Cornell (Engineering departments, Veterinary medicine, Weill Medical College in New York City) or outside of Cornell University, in academia or industry.

Select one course from 3 different topic areas (9 credits minimum required)

Topical Areas		*Courses that cover this area*	
Quantitative Physiology	S	BEE 3600	Molecular and Cellular Bioengineering (BME 3600)
	F	BEE 4600	Deterministic and Stochastic Modeling in Biological Engineering
	F	BME 4010	Biomedical Engineering Analysis (MAE 4660)
	S	BME 4020	Electrical and Chemical Physiology
	F	BME 4110	Science and Technology Approaches to Problems in Human Health
	S	CHEME 4810	Biomedical Engineering (BME 4810)
Instrumentation	S	BEE 4500	Bioinstrumentation
	F	BEE 4590	Biosensors and Bioanalytical Techniques
	F	BME 3300	Introduction to Computational Neuroscience (BIONB/PSYCH/COGST 3300)
	S	ECE 5020	Biomedical System Design (BME 5020)
Materials	F	AEP 4700	Biophysical Methods (BIONB 4700)
	F	BME 5850	Current Practice in Tissue Engineering
	S	BEE 3650	Properties of Biological Materials
	S	MSE 4610	Biomedical Materials and their Applications
	S	BME 5390	Biomedical Materials and Devices for Human Body Repair (FSAD 4390)
Mechanics	S	MAE 4640	Orthopaedic Tissue Mechanics (BME 4640)
	S	MAE 5650	Biomechanical Systems—Analysis and Design (BME 5650)
Analysis/Modeling of Biomedical Systems	S	BEE 3600	Molecular and Cellular Bioengineering (BME 3600)
	S	BEE 4530	CAE: Applications to Biomedical Processes (MAE 4530)
	F	BEE 4600	Deterministic and Stochastic Modeling in Biological Engineering
	F	BME 3300	Introduction to Computational Neuroscience (BIONB/PSYCH/COGST 3300)
	F	BME 4010	Biomedical Engineering Analysis (MAE 4660)
	S	ECE 5780	Computer Analysis of Biomedical Images (BME 5780)

-Some of these courses have prerequisites not included in the Biological Engineering curriculum.
-Courses listed in more than one area may be used to satisfy one area only. F = Fall, S = Spring

BIOPROCESS ENGINEERING CONCENTRATION

Increasingly, manufacturers are finding that the fastest, most environmentally sound, and most economical route to a product is through a biological system. From pharmaceuticals to foods to industrial enzymes, biological systems are being harnessed to increase product yield, purity, and efficacy. Bioprocess engineering is the use of cell culture, bacteria, cell free enzymes, and even farm animals (in short, any biological system) for the synthesis of industrially-relevant product, such as drugs, foods, and detergent additives. There are many steps to a bioprocess and, hence, many opportunities for biological engineers to get involved. The three main areas of interest are process development, product recovery, and validation (courses that have a particular focus in these areas are noted below). Much like chemical engineering, bioprocess engineers need a strong background in kinetics, thermodynamics, statistics, and chemistry (especially biochemistry). In addition, courses in food science, microbiology, cell biology, and physiology can be essential depending on where the student wants to work.

The educational objective for the concentration in bioprocess engineering is to relate the broader biological engineering program to the individual's interest in preparing for an industrial career or graduate study in areas related to bioprocess development, product recovery, or process validation and modeling. The concentration should guide the individual in choosing elective subjects that they will use in their life after graduation.

To further enhance the concentration and the curriculum in general, undergraduate research and independent study are encouraged. Such work could be with faculty members within Cornell (Engineering departments, Microbiology, Food Science) or outside of Cornell University, in academia or industry.

Select three courses from the list below (9 credits minimum required)

S	BEE 3600	Molecular and Cellular Bioengineering (BME 3600)[a, c]
F	BEE 3680	Animal Bioreactors[a]
S	BEE 4500	Bioinstrumentation[a]
S	BEE 4530	Computer aided Engineering (MAE 4530)[c]
F	BEE 4590	Biosensors and Bioanalytical Techniques[a, b, c]
F	BEE 4600	Deterministic and Stochastic Modeling in Biological Engineering
F	BEE 4640	Bioseparation Processes[b]
S	BEE 4840	Metabolic Engineering[a]
F	CHEM 3000	Quantitative Chemistry (does not count for Engr cr)[b]
S	CHEME 3320	Analysis of Separation Processes[b]
S	CHEME 3720	Introduction to Process Dynamics and Control[a]
S	CHEME 4700	Process Control Strategies[a]
F	CHEME 5430	Biomolecular Engineering of Bioprocess[a]
F	ORIE 5100	Design of Manufacturing Systems[a]
S	ORIE 4710	Applied Linear Statistical Models[c]

Some of these courses have pre-requisites not included in the Biological Engineering curriculum.

Topic Areas

[a]Research and Bioprocess Development
[b]Product Recovery
[c]Validation/Modeling

F = Fall
S = Spring

BIOENVIRONMENTAL ENGINEERING CONCENTRATION

The bioenvironmental engineering concentration is for students who want to apply their interest in biological systems to the environment. The natural environment is influenced to a great extent by the consortium of organisms that inhabit it. In order to understand the natural environment or to mitigate the negative impact of human activities we must understand not only fundamental biological processes (material covered in the core program), but we must understand how the natural environment works (for example how water cycles in the environment—hydrology) and how organisms interact with their environment. Courses suggested for this concentration include those that focus on the natural environment as well as engineered systems rely on biology to remediate contamination.

The educational objective of the concentration in bioenvironmental engineering is to relate the broader biological engineering program to the individual's interest in preparing for an industrial career or graduate study in areas related to environmental engineering, environmental sustainability, or environmental management. To further enhance the concentration and the curriculum in general, undergraduate research is encouraged.

Select three courses from the list below (9 credits minimum required)

S	BEE 3710	Physical Hydrology for Ecosystems
S	BEE 4010	Renewable Energy Systems
S	BEE 4350	Principles of Aquaculture
S	BEE 4710	Introduction to Groundwater (EAS 4710)
F	BEE 4730	Watershed Engineering
S	BEE 4740	Water and Landscape Engineering Applications
F	BEE 4750	Environmental Systems Analysis
S	BEE 4760	Solid Waste Engineering
F	BEE 4870	Sustainable Energy Systems
S	BEE 6510	Bioremediation: Engineering Organisms to Clean up the Environment
S	CEE 3510	Environmental Quality Engineering
S	CEE 4320	Hydrology
S	CEE 4360	Case Studies in Environmental Fluid Mechanics
F	CEE 4510	Microbiology for Environmental Engineering
F	CEE 4520	Water Supply Engineering
F	CEE 4540	Sustainable Small-Scale Water Supplies
S	CEE 5970	Risk Analysis and Management (TOX 5970)
F	CEE 6530	Water Chemistry for Environmental Engineering
F	CEE 6550	Transport, Mixing, and Transformation in the Environment
F	EAS 4570	Atmospheric Air Pollution

Some of these courses have pre-requisites not included in the Biological Engineering curriculum.

F = Fall
S = Spring