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DOC 2008-03 University of Dayton Proposal for New Graduate Degree Program: Master of Science in Bioengineering

University of Dayton. Graduate Leadership Council

DOC 08-03

PROPOSAL TO THE ACADEMIC SENATE

TITLE: University of Dayton Proposal for New Graduate Degree Program: Master of Science in Bioengineering

SUBMITTED BY: Graduate Leadership Council

DATE: 26 January 2009

ACTION: Legislative authority

REFERENCE: II.B.1.a

Background. The full proposal has been reviewed and approved by the Graduate Council of the College of Arts and Sciences; the School of Engineering Graduate Studies Committee; the School of Engineering Academic Leadership Committee; and the Graduate Leadership Council of the University.

Proposal
Master of Science in Bioengineering

University of Dayton
School of Engineering
(Department of Chemical and Materials Engineering)
and the College of Arts and Sciences

November 2008

EXECUTIVE SUMMARY

The University of Dayton is proposing to offer a post-baccalaureate Masters of Science (MS) degree program in Bioengineering. This program will be housed in the Department of Chemical and Materials Engineering, but will be a cooperative program between the School of Engineering (SOE) and College of Arts and Science (CAS). This unique collaborative effort between the SOE and CAS draws expertise from all areas of the University of Dayton and will offer a wide range of relevant courses within the program emphasis areas based, in part, on the significant, on-going research at UD. The program will be highly interdisciplinary and inclusive of several emphasis areas including Biomaterials & Biomechanics, Biosystems Engineering, Bioengineering Instrumentation, and Bioprocess Engineering and supports UD's strategic plan, which calls for such interdisciplinary activities in both academics and scholarship. The MS in Bioengineering will place emphasis on educating students with engineering or science-related backgrounds by incorporating coursework as well as conceptual and technical approaches from both the engineering and science arenas.

The proposed program consists of 12 semester-hours of core requirements; 12 hours of specialized advanced study in a selected emphasis area; and 6 hours of thesis or a 3-hour special capstone project plus one additional 3-hour elective course. The coursework includes both lecture and laboratory components. The proposed program is completed by 6 semester-hours of thesis or an alternate 3-hour capstone project that requires a high-level of independence, creativity and rigor. Student thesis and capstone advisory committees will be comprised of interdisciplinary teams of three faculty members, with at least one member from the SOE and one member from the CAS.

The launch of the MS in Bioengineering Program is planned to utilize currently available faculty and facilities. Some of the additional courses that are proposed for this program may, however, necessitate the hiring of adjunct and/or part-time faculty to back-fill current engineering courses while full-time faculty are engaged in course development. After the initial launch, this need should not be sustained since many of the new courses are electives that would be developed independent of the proposed program as faculty expertise in the supporting disciplines evolves strategically toward bioscience and bioengineering. Further, in alignment with the University's strategic plan to build capability in bioscience and bioengineering, new faculty members with specific expertise in bioengineering are already being hired to fill open positions. We expect this trend to continue and that the establishment of an interdisciplinary MS in Bioengineering program will also serve as an important inducement in hiring new faculty across campus. New faculty dedicated to this program would only be hired as future enrollments warrant.

We similarly plan to launch the program using existing laboratories and research space and phase in new resources in a fiscally responsible manner. There are already several academic

and research laboratory facilities that we will be able to use in the program, including the Tissue Regeneration & Bioengineering at Dayton (TREND) Center and Nanoscale Engineering, Science and Technology (NEST) facility. Although we will leverage existing resources to the extent possible, new laboratories, equipment, and space will be needed to support the proposed program, which will be evolved as our capabilities grow and developed to serve multiple disciplines and purposes. The creation of a dual-use lab facility in Chemical Engineering, especially during its initial start-up, will enable us to leverage funding from teaching, research, and administrative sources. For example, while we expect this specific lab to require about $100,000 to develop, its cost will be covered through a combination of endowed departmental funds, routine engineering instructional funds, external research funds, and external educational grants. During the initial years of the new program, careful coordination among faculty within participating units will also allow for use of existing space and instrumentation to support the courses offered within the Bioengineering program. As the program grows, we expect stakeholders will see the value in investing in dedicated laboratory space and equipment to meet the evolving needs of both the program and associated faculty research.

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PROPOSAL
MASTER OF SCIENCE IN BIOENGINEERING
UNIVERSITY OF DAYTON

Overview

The School of Engineering, in cooperation with the College of Arts and Sciences, at the University of Dayton proposes to offer a new Master of Science Degree in Bioengineering. The program will be highly interdisciplinary and inclusive of several emphasis areas including Biomaterials & Biomechanics, Biosystems Engineering, Bioengineering Instrumentation, and Bioprocess Engineering. It will benefit from the support of several departments within the School of Engineering (SOE) and the College of Arts & Science (CAS) offering a wide range of relevant classes. The rationale for offering this Bioengineering program has its foundation in significant, on-going research at UD in the emphasis areas, and does not overlap in scope or objective with current biomedical engineering programs offered at other institutions in the state. Also, the program is directly supportive of UD's strategic planning which calls for such interdisciplinary activities both in academics and scholarship. The post-baccalaureate Masters of Science (MS) degree program in Bioengineering will place emphasis on educating students with engineering or science-related backgrounds by incorporating coursework as well as conceptual and technical approaches from both the engineering and science arenas. The program coursework and research opportunities will be co-delivered by faculty from the SOE and the CAS.

Relation to Objectives of the University

The University of Dayton has been engaged for a number of years in a systematic prioritization process to identify strategic collaborative initiatives within science and engineering. Most notably, a team of faculty members from the sciences and engineering and personnel from the University of Dayton Research Institute (UDRI) worked during the 2003-04 academic year to identify key areas of focused research that would enable development of a strategy for science and engineering research at the University[1]. The methodology used included solicitation of proposed research areas from faculty and research personnel across the campus and the screening of the proposed areas on the basis of factors such as current University expertise, funding potential, the potential for collaboration, and linkage to graduate programs.

As a consequence of this process, a number of research areas related to bioscience and bioengineering emerged as priorities for the University, resulting in substantial investments in research capability related to topics such as sensors and tissue regeneration and engineering. For example, the University has established the Tissue Regeneration & Bioengineering at Dayton (TREND) Center that fosters advanced academic training at the graduate level,

[1] Bouchard, M., Eylon, D, and Tsonis, P. (2004), *Strategic Collaborative Research at the University of Dayton*, Final Report to the Office of the Provost, University of Dayton.

technology transfer, and research collaboration between the College of Arts and Sciences, the School of Engineering, and UDRI. In 2004, UD and the State of Ohio also invested over $10 million to establish the Nanoscale Engineering, Science and Technology (NEST) facility that houses a variety of state-of-the-art equipment and instrumentation which is available to industry and academics to pursue specific research projects in diverse fields including bioengineering. On-going research at UD in bioscience and bioengineering totaled nearly $17 million in 2008.

Investment in this field is also supported by the University's participation in the Ohio Board of Regents (OBR) Economic Growth Challenge/Innovation Incentive (EGC/II) Program which was initiated in 2006 and which provides funds at UD to support research in Bioscience and Bioengineering at the Nanoscale within the three focus areas of Tissue Regeneration, Biomaterials, and Biosensors. Although primarily intended to incentivize enhanced program focus through effective doctoral program investment reallocation, the Innovation Incentive Program is also intended to attract preeminent faculty researchers and build world-class research capacity in areas of strategic importance to the University and the state of Ohio. Toward this end, the University committed in 2008 to allocate the total EGC/II FY 08 and FY 09 funding and corresponding base-budget match to provide a highly competitive startup package—including the possible enhancement of laboratory facilities—for a new faculty member, most likely in the Department of Biology, with expertise in biosensors who could impact both academic and research initiatives in the bioscience and bioengineering fields.

The proposed Master of Science program in Bioengineering is a curricular outgrowth of the University's strategic efforts to integrate its well-established physical science and engineering expertise with its rapidly-growing biological and bioengineering research capabilities. The intent is to leverage and strengthen collaborative activities in both academics and scholarship across our campus in the dynamic areas that lie at the intersection of bioscience and engineering.

Relation to Other Programs at the University

The interdisciplinary bioengineering M.S. degree program being proposed blurs the lines between several traditional academic disciplines and identifies four emphasis areas that align our unique strengths with the graduate and advanced learning needs of the region and the State of Ohio. These emphasis areas—Biomaterials & Biomechanics, Biosystems Engineering, Bioprocess Engineering, and Bioengineering Instrumentation—provide a thematic basis for: (a) augmenting our current funded research in these areas and (b) developing rigorous programming and research opportunities to train post-baccalaureate students. The intent is for the impact of this program to be university-wide. The results of this approach will not only be a more effective avenue for educating students in terms of their interdisciplinary knowledge, but will also create a powerful synergy that quickly drives the expansion of academic coursework and research capability in the defined focus areas.

The proposed program will benefit from, and also provide benefit to, several graduate degree programs within the College of Arts & Science and the School of Engineering that comprise the University's strong Science, Technology, Engineering, and Mathematics (STEM) portfolio. These programs include Biology (both MS and PhD), Chemical Engineering (MS), Civil and Environmental Engineering (both MS and PhD), Electrical Engineering (MS and PhD), Electro-Optics (MS and PhD), Materials Engineering (MS and PhD), and Mechanical Engineering (MS and PhD). These graduate programs are all outgrowths of UD's tradition of responding to the research and educational needs of the Dayton region, including Wright-Patterson Air Force Base (WPAFB). The proposed MS degree in Bioengineering responds similarly to these needs and will enable cross-fertilization among these already strong programs. The wide range of courses that comprise the proposed program and its emphasis areas will also serve as key electives for students within the related existing graduate programs and, as such, provide a critical means of fostering interdisciplinary discussion and collaboration. It will also strengthen the undergraduate programs in the related STEM fields by providing a source of advanced upper-level electives for highly qualified students.

Faculty collaboration will also be fostered through their participation on student thesis advisory committees and interactions within curriculum development committees. As courses evolve, they may also be team-taught by faculty across disciplines. For example, two faculty members in Chemical Engineering and Biology were awarded an internal 2008 LTC Innovations Grant for the collaborative proposal entitled, "Interdisciplinary Biological Systems Engineering as a Model for Curricular Development in Bioengineering." The objective of this effort is to develop a Biological Systems Engineering course as a pragmatic and effective model of future interdisciplinary curricular development in bioengineering. The resulting course will be jointly taught by the two faculty members whose combined expertise is in the areas of physiology, molecular genetics, chemical engineering, and fluid flow mechanics. Such multidisciplinary academic and research partnerships are not unique at UD. For example, faculty in the SOE and CAS have joined with researchers in UDRI to focus on the development of a new center for Sustainability, Energy and the Environment (SEE), which is designed to create and implement creative bioengineering solutions in these areas.

In summary, the proposed Masters of Science in Bioengineering program represents a unique curricular component and a natural outgrowth of UD's overall strategy to grow its expanding academic and research expertise in the field.

Proposed Curriculum

Admissions Requirements

- Undergraduate Degree Requirements: An undergraduate engineering degree or a Bachelor of Science (or equivalent) in Biology, Biochemistry, Chemistry, Computer Science, or Physics.

- Prerequisite Undergraduate Coursework: Numerical methods, statistics, calculus, differential equations, computer programming, 1 year biology, 1 year introductory chemistry, 1 year physics. One year of Organic Chemistry and lab is highly recommended and may be required for certain emphasis areas.

- Other Requirements: Additional undergraduate courses may be required depending on area of research.

Program Requirements

The proposed program consists of 12 semester-hours of core requirements; 12 hours of specialized advanced study; and 6 hours of thesis or a 3-hour special capstone project plus one additional 3-hour elective course. The coursework includes both lecture and laboratory components. The core requirements are designed to prepare both engineering and science undergraduates for advanced work in bioengineering. Students advance through the balance of the curriculum according to an individualized program of study, developed in consultation with a multidisciplinary advisory team comprised of faculty from both the SOE and CAS. The 12 hours of specialized advanced study would normally be satisfied by students selecting one of four emphasis areas, currently envisioned as Biomaterials & Biomechanics, Biosystems Engineering, Bioprocess Engineering, or Bioengineering Instrumentation. In exceptional cases, a student may—with the advance approval of the advisory team, his or her thesis advisor, and program director—define an individualized emphasis area.

The proposed program is completed by 6 semester-hours of thesis or an alternate 3-hour capstone project that requires a high-level of independence, creativity and rigor plus one additional 3-hour elective course. All students, especially those who might wish to pursue further study in the field, are encouraged to complete a thesis. Full-time students who choose to conduct thesis research will normally begin an independent research project the first term of the program, which will culminate in a written thesis and oral defense of the original research. It is anticipated that the research will lead to peer-reviewed publication(s). Part-time students electing the thesis option will begin thesis research in the summer after the first year of the program. Students who elect to complete a capstone project will be required to provide a final written and oral report upon completion of the project. The capstone project offers students working on proprietary bioengineering research and development or contract-sponsored bioengineering research for the government or industry partner, an opportunity to pursue these types of projects for credit. Student thesis and capstone advisory committees will be comprised of interdisciplinary teams of three faculty members, with at least one member from the SOE and one member from the CAS.

Appendix A provides details of the curriculum including the course structure envisioned within each of the emphasis areas.

Relation to Similar Programs in the State

This program has been designed not to overlap significantly in scope or objective with current programs offered at other institutions in the state (Case Western Reserve University, Ohio University, the Ohio State University, the University of Akron, the University of Cincinnati, the University of Toledo, and Wright State University, as well as a proposed program at Cleveland State University) as these tend to have a much more overt biomedical emphasis and are aligned with Schools of Medicine as well. Our objective has been to define emphasis areas that complement our existing capabilities in the bioengineering field while minimizing the potential

duplication with the other programs. For example, rather than emphasizing pharmaceutical or medical research, the proposed program will provide a formal curricular avenue for applying bioscience and bioengineering principles and concepts to current areas of strength, including materials, sensors, imaging, therapeutic devices and instrumentation.

The proposed MS degree program in Bioengineering is also distinctive in that it will have an integrated core of both engineering and science faculty who will participate in the delivery of the curriculum and research/project opportunities to a multidisciplinary cohort of students within the program. This approach will foster the development of degree recipients who have practical, conceptual, and technical expertise in the biosciences as well as in engineering. Further, it will enhance the ability of bioengineering students to complement their undergraduate skills with a working knowledge of the language of engineering and biological sciences, as well as the engineering and science-based approaches, tools, and skills required for solving problems in bioengineering.

Need and Projected Enrollments

Evidence of need for this program includes the impact of recent Base Realignment and Closure (BRAC) legislation that will bring approximately 1,000 health and biomedical-related training and R&D jobs to the Dayton area by 2011. Additionally, the Occupational Outlook Handbook, 2008-09 Edition, published by the U.S. Bureau of Labor Statistics (BLS) indicates that biomedical engineers (the broad BLS classification that would encompass our graduates) are expected to have 21 percent employment growth over the 2006-16 projections decade, which places the field within the top tier with respect to projected growth potential. Further the BLS also states that within this field, “unlike many other engineering specialties, a graduate degree is recommended or required for many entry-level jobs.” This projected growth and demand for graduates is also reflected in the many related programs being developed nationwide, including the recently proposed program at Cleveland State University.

Unlike many traditional engineering master’s programs, the proposed bioengineering program is designed to accommodate students with undergraduate degrees in a wide variety of disciplines, including engineering, the life/physical/natural sciences, computer science and mathematics. Initial estimates are for an initial class of approximately 10 students with an increase to about 25 total students during the second and third years of the program. We expect these students to be primarily part-time and live and work in the local region. Larger numbers of full-time students are anticipated as expected growth in extramural research funding permits the funding of graduate research assistants. We also anticipate that some of our current undergraduate students will enter this program upon completion of their undergraduate work.

The proposed program will also utilize existing UD and SOE programs for attracting and retaining students from underrepresented groups. The SOE in particular employs a full-time program manager who is a highly qualified engineer to administer its Women-in-Engineering and Minority Engineering Programs. The University is also in the process of strengthening its

relationships with Central State University, Wilberforce University and St. Mary's University (the Marianist University in San Antonio, TX established by the same religious order that founded UD) to help enhance the recruitment of minorities. Additionally, the CAS and SOE are active participants in the state-wide Louis Stokes Alliance for Minority Participation program which provides support for minority STEM majors at the undergraduate level.

Administrative Arrangements and Faculty Resources

The program will be administratively positioned in the Chemical and Materials Engineering Department of the School of Engineering. This department has been in existence since 1910 and currently offers the BS degree in Chemical Engineering, the MS degree in both Chemical Engineering and Materials Engineering, and the PhD in Materials Engineering. A program director reporting to the chemical and materials engineering department chair will be appointed to administer the operation of the program on a day-to-day basis. An internal multidisciplinary steering committee comprised of faculty from the SOE and CAS will advise the director on curriculum components of the program. Although the program will be housed in the Chemical and Materials Engineering department, the course offerings and scholarship activities will include SOE faculty and students from several other programs such as Mechanical & Aerospace Engineering, Electrical & Computer Engineering, Civil & Environmental Engineering, and Electro-Optics. Within the CAS, the Departments of Biology, Chemistry, Computer Science, Mathematics, and Physics will be involved in delivering courses, and advising/mentoring students in research projects or thesis.

Through their research, scholarship, and professional activities, several of our graduate faculty researchers in these Departments have attained international reputations as leaders in their respective fields with specific expertise in bioscience and bioengineering. Collectively, the five STEM departments/programs at UD offering Ph.D. degrees have more than 35 full-time graduate faculty members with expertise and interests aligned with the MS in Bioengineering Program. The five additional, related academic departments contribute an additional 61 faculty to serve on graduate committees (Chemical Engineering-8, Chemistry-10, Computer Science-12, Mathematics-19, and Physics-12). Furthermore, there are dozens of research scientists and engineers at the UDRI holding joint appointments as faculty in academic departments, and additional adjunct faculty at Air Force Research Laboratories (AFRL) and other UD research partners in the region.

The program coursework and research opportunities will be co-delivered by faculty from the SOE and the CAS. Our plan is to launch the program by utilizing existing faculty and facilities. Several of the courses are already being taught as either departmental requirements or electives. Additionally, current faculty members are already heavily involved in research in the emphasis areas. Additional courses, including some that will be team-taught, will be developed over the next few years utilizing existing faculty resources. Although this may require the hiring of adjunct faculty to teach one or two courses in the short term while full-time faculty are engaged in course development, the need should not be dramatic since many of the new courses are electives that would be developed independent of the proposed program as faculty expertise in the supporting disciplines evolves strategically toward bioscience and bioengineering. Further, in alignment with the University's strategic plan to build capability in bioscience and bioengineering, new faculty members with specific expertise in bioengineering are already being hired to fill open positions; two such faculty (one in the Department of Chemical & Materials Engineering and another in Mechanical & Aerospace Engineering) have

already been hired and will start during the 2008-09 academic year. We expect this trend to continue and, symbiotically, that the establishment of an interdisciplinary MS degree in Bioengineering will also serve as an important inducement in hiring new faculty across campus.

This joint venture into offering an interdisciplinary MS degree in Bioengineering is thus a natural and complementary extension of the successfully-executed and existing graduate programs in the SOE and CAS. The program will be phased in over a two-to-three year period. During the first year the core courses will be offered. The courses for the emphasis areas will be phased in during the following years as a function of student focus and faculty availability. It is anticipated that the first such courses to be offered will be those that serve more than one emphasis area. While the proposal ambitiously outlines four emphasis areas, reflecting the keen faculty interest that the concept has generated on campus, those emphasis areas will be phased in (and evolved) over time as well, starting with just one or two. It is acknowledged that the enrollments projected for the Bioengineering program alone cannot be expected to provide the critical mass needed to routinely offer courses within four emphasis areas. However, we do expect those courses to be offered routinely in the long term since they will also be populated by substantial numbers of students in related disciplines. For example, the new course on Transport Phenomena in Biological Systems is being offered in the Winter, 2009 semester for students in Biology and Chemical Engineering; the proposed new electives in Biomaterials would be of keen interest to students in materials Engineering and related fields; and so on.

Resource Needs

As stated above, our plan is to launch the program by utilizing currently available faculty and faculty positions. New faculty dedicated to this program would only be hired as future enrollments warrant. We similarly plan to launch the program using existing laboratories and research space and phase in new resources in a fiscally responsible manner.

We already have several academic and research laboratory facilities that we will be able to use in the program, including the TREND and NEST facilities mentioned previously. Faculty research facilities are also located in the Science Center, Kettering Laboratories, and within UDRI. In addition, Dr. Liming Dai's laboratory for nanoscale research represents an investment of several million dollars over the last several years. We are actively collaborating with Kettering Medical Center in the area of bio-medical imaging and with the Orthopedic Residency Program at Grandview Medical Center and Clemson University in the biomaterials area. In addition, the capstone project that non-thesis students will be required to complete will afford the opportunity for work to be performed on proprietary bioengineering research & development or contract-sponsored bioengineering research for the government (most notably the AFRL at Wright-Patterson Air Force Base) or industry partners.

Although we will leverage existing resources to the extent possible, new laboratories, equipment, and space will be needed to support the proposed program, but these, too, will be evolved as our capabilities grow and developed to serve multiple disciplines and purposes. For example, the laboratory facilities and equipment needed for the course in Transport

Phenomena in Biological Systems would be developed to serve multiple disciplines (e.g., it could be used within a general Chemical Engineering course on transport phenomena) and related faculty research as it would be needed to support the specific course only during a small portion of a typical week. The creation of this lab as a dual-use facility, especially during its initial start-up, also enables us to leverage funding from teaching, research, and administrative sources. For example, while we expect this specific lab to require about $100,000 to develop, its cost will be covered through a combination of endowed departmental funds, routine engineering instructional funds, external research funds, and external educational grants. During the initial years of the new program, careful coordination among faculty within participating units will also allow for use of existing space and instrumentation to support the courses offered within the Bioengineering program. As the program grows, we expect stakeholders will see the value in investing in dedicated laboratory space and equipment to meet the evolving needs of both the program and associated faculty research.

As the supporting academic fields have increased emphasis in bioscience and bioengineering in recent years, our library holdings in the bioscience and bioengineering have implicitly grown as well. As such, and with the wealth of materials available today electronically through OhioLink, no special infusion of library resources will be needed to support the proposed program. Consultation with the Associate Dean for Collections and Operations confirms that emerging needs can be reasonably expected to be accommodated within the Roesch Library's normal and ongoing acquisitions process.

APPENDIX A: PROPOSED CURRICULUM

I. Core Coursework (4 courses/12 semester hours):

CME XXX Fundamentals of Biology for Bioengineers
- or - CME XXX Fundamentals of Engineering for Bioengineers

CME 590 Introduction to Bioengineering

MTH XXX Applied Biostatistics
- or - MTH 547 Statistics for Experimenters
- or - BIO 550 Analysis and Interpretation of Biological Data

CME XXX Fundamentals of Bioengineering Experimentation

II. Emphasis Area (4 courses/12 semester hours):

A. Biomaterials & Biomechanics

1. Required courses (2 courses/6 semester hours):

   MAT XXX Biomaterials I: Polymers, Naturals Materials, and Nanomaterials
   - and - MAT XXX Biomaterials II: Metals, Ceramics, and Composites

   - or -

   EGM / MEE XXX Foundations of Biomechanics
   - and - MAT XXX Biomaterial Characterization Techniques

2. Elective courses (2 courses/6 semester hours):

   BIO 404 Physiology II

   BIO 524 Advanced Cell Biology

   BIO 594 Molecular Biology

   CHM XXX Advanced Biochemistry

   CME 591 Biomedical Engineering

   CME XXX Bioproduct Design

   ECE XXX Biomimetics

   MAT XXX Biomaterials I: Polymers, Natural Materials, and Nanomaterials

   MAT XXX Biomaterials II: Metals, Ceramics, and Composites

   MAT / MEE XXX Surface and Interface Performance of Biological Materials

   PHY XXX Biophysics

B. Biosystems Engineering

1. Required courses (2 courses/6 semester hours):

   CME 595/BIO 596 Transport Phenomena in Biological Systems

   CME 591 Biomedical Engineering

2. Elective courses (2 courses/6 semester hours):

   BIO 404 Physiology II

   BIO 523 Advanced Microbiology

   BIO 524 Advanced Cell Biology

   BIO 594 Molecular Biology

   CHM XXX Advanced Biochemistry

   CME XXX Bioproduct Design

   CME XXX Kinetics and Thermodynamics of Biological Systems

   MAT XXX Biomaterial Characterization Techniques

   MAT XXX Biomaterials I

   MAT XXX Biomaterials II

C. Bioengineering Instrumentation

1. Required courses (2 courses/6 semester hours):

   ECE XXX Biomimetics

   ECE XXX Biophotonics

2. Elective courses (2 courses/6 semester hours):

   BIO 524 Advanced Cell Biology

   BIO 594 Molecular Biology

   CHM XXX Advanced Biochemistry

   CME 592 Chemical and Biological Sensors

   ECE 563 Digital Image Processing

   ECE XXX Bioinstrumentation Engineering

   ECE XXX Database Systems for Bioinformatics

   MAT XXX Biomaterial Characterization Techniques

D. Bioprocess Engineering

1. Required courses (2 courses/6 semester hours):

   CME XXX Introduction to Bioprocess Engineering

   CME XXX Kinetics and Thermodynamics of Biological Systems

2. Elective courses (2 courses/6 semester hours):

   BIO 505 Microbial Ecology

   BIO 523 Advanced Microbiology

   BIO 524 Advanced Cell Biology

   BIO 560 Introduction to Bioinformatics

   CHM 427 Medicinal Chemistry

   CHM XXX Advanced Biochemistry

   CME 595/BIO 596 Transport Phenomena in Biological Systems

   CME XXX Bioproduct Design

   CME XXX Bioseparations

III. Capstone Requirement (6 semester hours):

Six semester hours of thesis

- or -

Three semester hours of a capstone project and an approved Bioengineering elective course

Additional notes on the curricular requirements:

- 'Fundamentals of Biology for Bioengineers' is a core course designed for Bioengineering masters students whose undergraduate degree is in engineering, and who have not taken undergraduate courses in Cell Biology, Genetics, Microbiology, Molecular Biology, and Physiology, as an overview of general topics in each of these sub-disciplines. Bioengineering masters degree students who enter the program with a major or minor in biology or pre-medicine do not need to take this course. Undergraduate students considering applying to the MS in Bioengineering program are highly encouraged to enroll in undergraduate level courses in Cell Biology, Microbiology, Molecular Biology, Genetics, and Physiology.

- 'Fundamentals of Engineering for Bioengineers' is a course designed for Bioengineering masters students with a bachelor of science degree who have not had courses in

engineering. The topics covered in this course include mass and energy balance, and an introduction to thermodynamics.

- The core 'Biostatistics' course will be waived for students who have taken an undergraduate or graduate course in biostatistics or the equivalent.

- The core 'Introduction to Bioengineering' will be waived for students who have taken an undergraduate or graduate course in Bioengineering.

APPENDIX B: COURSE SYLLABI FOR PROPOSED AND REVISED COURSES

CME XXX FUNDAMENTALS OF BIOLOGY FOR BIOENGINEERS

Objective:
The course is designed for students with undergraduate majors in engineering or non-biological sciences. The focus of the course is to provide a common broad base of basic knowledge and terminology in the biological sciences required for coursework in the bioengineering emphasis tracts.

Prerequisites:
Graduate standing in Bioengineering and 1 year of Organic Chemistry (highly recommended).

Topics to be covered:

- Review of general biology: Biomolecules, enzymes, cellular organelles
- Molecular Biology: Nucleic acids, proteins
- Genetics, genomes: Gene structure/function
- Genetic regulation: DNA replication, transcription, translation
- Cell biology: Membrane transport, cell cycle regulation, cell division, profileration
- Cell signaling
- Tissue/Organ Biology: Structure, development
- Systems Biology, Physiology
- Microbiology
- Molecular Evolution
- Bioinformatics

CME XXX FUNDAMENTALS OF ENGINEERING FOR BIOENGINEERS

Objective:
The course is designed for students with undergraduate majors in science. The focus of the course is to provide a common broad base of basic knowledge and terminology in engineering required for coursework in the bioengineering emphasis tracts. It will cover basic mass and energy conservation and an introduction to thermodynamics.

Prerequisites:
Graduate standing in Bioengineering.

Topics to be covered:

- Mass balances
  - Degrees of Freedom
  - Multiple streams and recycle
  - Reactive systems
- Multicomponent systems
  - Humidification
  - Raoult's law
  - Partial pressures
- Energy balances
- Introduction to thermodynamics

CME 590 INTRODUCTION TO BIOENGINEERING

Objective:
Overview of bioengineering, transport phenomena in biological systems, kinetics of biological reactions.

Prerequisites:
Graduate standing in Bioengineering, Fundamentals of Biology for Bioengineers or equivalent, and Fundamentals of Engineering for Bioengineers or equivalent.

Topics to be covered:

- Overview of bioengineering
- Introduction to transport phenomena concepts
- Applications of transport phenomena in bioengineering
  - Physiological systems/Systems engineering
  - Biomaterials/Biomechanics
  - Bioinstrumentation
  - Bioprocess engineering
- Biological reaction kinetics

MTH XXX APPLIED BIOSTATISTICS

Objective:
Introduction to statistical techniques with emphasis on applications in health related sciences. This course will be accompanied by examples from biological, medical, and clinical applications.

Prerequisites:
Graduate standing in Bioengineering.

Topics to be covered:

- Data collection
- Summarizing and exploring data
- Sample size determination
- Sample distributions
- Basic concepts of inference
- Inferences for single and two samples
- Inferences for proportions and count data
- Simple linear regression and correlation
- Multiple linear regression
- Parametric analyses
- Non-parametric analyses
- Analysis of variance
- Factorial Design

MTH 547 STATISTICS FOR EXPERIMENTERS

Objective:
Covers those areas of design of experiments and analysis of quantitative data that are useful to anyone engaged in experimental work. Designed experiments using replication and blocking. Use of transformations. Applications of full and fractional factorial designs. Experimental design for developing quality into products using Taguchi methods.

Prerequisites:
Graduate standing in Bioengineering.

Topics to be covered:

- Introduction
- Comparing two entities
- Randomized blocks and designs with more than one blocking variable
- The 2^k factorial design
- Fractional factorial design
- Additional fractionals and analysis
- Factorial designs and data transformations
- Multiple sources of variation

BIO 550 ANALYSIS AND INTERPRETATION OF BIOLOGICAL DATA

Objective:
An introductory class, designed as a first course in biological data analysis using available software. The objective of the course is to introduce students to the concepts and principles of biological data analysis, with numerical examples analyzed using Microsoft Excel and the statistical software SPSS, and to attempt to provide realistic examples from the literature that illustrate the concepts learned in class.

Prerequisites:
1 year of introductory biology; Graduate standing in Biology or Bioengineering.

Topics to be covered:

- Data collection
- Summarizing and exploring data
- Sample size determination
- Sample distributions
- Basic concepts of inference
- Inferences for single and two samples
- Inferences for proportions and count data
- Simple linear regression and correlation
- Multiple linear regression
- Parametric analyses
- Non-parametric analyses
- Analysis of variance
- Factorial Design
- Phylogenetic reconstruction

CME XXX FUNDAMENTALS OF BIOENGINEERING EXPERIMENTATION

Objective:
A one semester lecture/laboratory based course in basic biology laboratory techniques, generating testable hypotheses, formulating experimental design, report writing, and scientific presentation.

Prerequisites:
Graduate standing in Bioengineering.

Co-requisites:
Fundamentals of Biology for Bioengineers or equivalent.

Topics to be covered:

Basic lab techniques: Lab safety, solutions, sterile techniques, measuring, dispensing
Microbiology, staining, plating
Recombinant DNA, plasmids, transformation
DNA isolation, characterization by spectrophotometery, gel electrophoresis
PCR
RNA isolation, characterization by spectrophotometery, gel electrophoresis
Quantitative RT-PCR
Protein isolation, quantification, characterization by SDS PAGE
Western Blotting
Cell/Tissue culture
Light microscopy: Tissue fixation, histology staining
Bioinformatics

AND 3 of the following:

Microbial Fermentation Lab
Cellular/Protein Recovery Lab (Crossflow Filtration)
Immobilized Enzyme Kinetics Lab
Column Purification Lab
Biological Transport (Dialysis) Lab
Biological Instrumentation Lab
Biosensor/MEMS Lab

MAT XXX BIOMATERIALS I: POLYMERS, NATURAL MATERIALS, AND NANOMATERIALS

Objective:
An introduction to the fundamentals of biomaterials with a specific focus on polymers, natural materials, and nanomaterials.

Prerequisites:
Graduate standing in Bioengineering.

Topics to be covered:

- Introduction
- Bio-polymers
- Structure-property relationships
- Applications
- Cellular interactions
- Properties
- Product development

MAT XXX BIOMATERIALS II: METALS, CERAMICS, AND COMPOSITES

Objective:
An introduction to the fundamentals of biomaterials with a specific focus on metals, ceramics, and composites.

Prerequisites:
Graduate standing in Bioengineering.

Topics to be covered:

- Introduction
- Metallic biomaterials, focus on implantable prosthesis and devices
- Ceramic biomaterials, bone, cartilage, glasses
- Biomaterial composites
- Hard tissue response

EGM / MEE XXX FOUNDATIONS OF BIOMECHANICS

Objective:
Study of movement/kinesiology, anatomy, muscular and skeletal, medical prosthetic design.

Prerequisites:
Graduate standing in Bioengineering.

Topics to be covered:

- Human movement
- Mechanical concepts
  - Functional Anatomical Analysis
  - Force-Motion Principles
- Musculoskeletal System Kinetics
  - Stress, strain, viscoelasticity
  - Bone, ligaments, and muscle
- Linear and Angular Kinetmatics
- Linear Kinetics
- Angular Kinetics
- Fluid Mechanics
- Applications of Biomechanics

MAT XXX BIOMATERIAL CHARACTERIZATION TECHNIQUES

Objective:
A lecture/laboratory based course which introduces students to specialized techniques used in the characterization of biological materials.

Prerequisites:
Graduate standing in Bioengineering, Fundamentals of Biology for Bioengineers or equivalent, and Fundamentals of Engineering for Bioengineers or equivalent.

Topics to be covered:

Imaging electron spectroscopy for chemical analysis (ESCA)
Secondary ion mass spectrometry (SIMS)
Thermal characterization: Differential scanning calorimetry (DSC), Thermogravimetric analysis (TGA)
Molecular weight analysis: dynamic light scattering, solution viscometry, gel permeation chromatography
Microscopy (light, fluorescent, confocoal, SEM, TEM, AFM)
Nuclear magnetic resonance (NMR)
Spectroscopy (vibrational, infrared, Raman, near infrared, mass, electrospray mass, MALDI-TOF mass, x-ray photoelectron)
Surface characterization: (contact angle analysis, Fourier transform infrared)
Engineering biomaterials surfaces
Nanomaterials surface properties

CME 595 / BIO 596 TRANSPORT PHENOMENA IN BIOLOGICAL SYSTEMS

Objective:
An integrated interdisciplinary systems-based examination of biological transport phenomena (momentum, heat and mass) and thermodynamics through mathematical modeling and biological processes as applied to two key physiological systems: the respiratory system and cardiovascular system.

Textbook:
Transport Phenomena in Biological Systems: A Textbook for Biomedical Engineers, G.A. Truskey, F. Yan, and D.F. Katz, Prentice Hall, 2004.
ISBN 0130422045

Prerequisites:
Graduate standing in Bioengineering, Introduction to Bioengineering, and Fundamentals of Biology for Bioengineers or equivalent.

Topics to be covered:

- Review of Transport Processes and Physiological Systems
  - Transport Processes
  - Transport within Cells / Transcellular Transport
  - Physiological Transport Systems
  - Application of Transport to: Disease Pathology, Treatment, Device Development
- Introduction to Physiological Fluid Mechanics
  - Momentum Transport Concepts
  - Navier-Stokes
  - Fluid Flow in Circulation and Tissues
- Mass Transport in Biological Systems
  - Mass Transport Concepts
  - Convection
- Transvascular Transport
- Biological Systems Level Analysis (Cardiovascular/Respiratory)
- Biological Transport in the Cardiovascular System
  - Anatomy of the CVS/Anatomy of the Heart
  - Cardiac Cycle; Excitation Contraction Coupling; Wigger's Diagram
  - Fluid Flow Mechanics/Hemodynamics
- Biological Transport in the Respiratory System
  - Anatomy/Physiology of Ventilation
  - Gas Exchange Transport Phenomena
- Systems Biology of Complex Physiological Phenotypes
  - IDDM and NIDDM
    - Pathophysiology of Cardiovascular Disease: Atherosclerosis, MI, CVD, Congestive Heart Failure
    - Pathophysiology of Lung Disorders

CME 591 BIOMEDICAL ENGINEERING

Objective:
Introduction to the fundamental concepts in biomedical engineering with a special focus on chemical engineering applications. Biomedical topics include overviews of areas such as biomaterials, tissue engineering, biosensors and biomedical engineering technology.

Prerequisites:
Graduate standing in Bioengineering, Fundamentals of Biology for Bioengineers or equivalent, Fundamentals of Engineering for Bioengineers or equivalent, and Introduction to Bioengineering.

Topics to be covered:

- Introduction to biomedical engineering
- Review of anatomy and physiology
- Biomechanics
- Biomaterials
- Tissue engineering
- Bioinstrumentation
- Bioelectric phenomena
- Medical imaging

ECE XXX BIOMIMETICS

Objective:
An introduction to biologically inspired materials, including using biological models applicable to engineering and biologically inspired materials, structures, sensors, control, adaptability, intelligence.

Textbook:
Biomimetics: Biologically Inspired Technologies, Y. Bar-Cohen, Taylor and Francis, 2006. ISBN 0-8493-3163-3.

Prerequisites:
Graduate standing in Bioengineering.

Topics to be covered:

- Introduction to biomimetics
- Genetic algorithms
- Biomimetic control
- Application to robotics
- Application to molecular design
- Application of biomaterials
- Biologically inspired optics
- Artificial muscles

ECE XXX BIOPHOTONICS

Objective:
An introduction to photonic strategies by reviewing the basic principles of optics, fundamentals of lasers, light-matter interactions, optical spectroscopy, optical microscopy, optical biosensors, and the application of these techniques to address fundamental questions in the life and health sciences.

Textbook:
Introduction to Biophotonics, P.N. Prasad, Wiley, 2003.

Prerequisites:
Graduate standing in Bioengineering.

Topics to be covered:

- Introduction to photonics
- Biophotonics techniques
  - Biofunction related optical phenomena
  - Principles and techniques of optical bio-imaging
  - Optical biosensors
  - Optical biomanipulations
- Applications of biophotonics
  - Biophotonics in biotechnology
  - Biophotonics in medicine

CME XXX INTRODUCTION TO BIOPROCESS ENGINEERING

Objective:
This course will serve as an introduction to the fundamental concepts of bioprocess engineering / biochemical engineering in small and large scale facilities.

Prerequisites:
Graduate standing in Bioengineering, Fundamentals of Biology for Bioengineers or equivalent, and Fundamentals of Engineering for Bioengineers or equivalent.

Topics to be covered:

- Cell structure, microorganisms, and nutrients
- Enzyme kinetics
- Immobilized enzyme kinetics
- Metabolic pathway engineering
- Fermenter design
- Sterilization processes
- Downstream processes

CME XXX KINETICS AND THERMODYNAMICS OF BIOLOGICAL SYSTEMS

Objective:
This course will cover biological reaction kinetics, enzyme reactions, bioreactor and fermenter design, design for optimum selectivity, stability and transient behavior, ideal reactors and non-ideal reactors, process troubleshooting. The course will also cover biochemical thermodynamics, and equilibria.

Prerequisites:
Graduate standing in Bioengineering, Fundamentals of Biology for Bioengineers or equivalent, Fundamentals of Engineering for Bioengineers or equivalent, and Introduction to Bioengineering.

Proposed texts: Biological Thermodynamics by Donald T. Haynie; Thermodynamics and Kinetics for the Biological Sciences by Gordon G. Hammes.

Topics to be covered:

- Energy Transformation – Carbon, energy, and life
- First Law of Thermodynamics
  - Heat capacity
  - Energy conservation in living organisms
- Second Law of Thermodynamics
  - Isothermal systems
  - Protein denaturation
  - Irreversibility
- Gibbs Free Energy
  - Equilibrium
  - Reversible Processes
- Application of Gibbs Free Energy
  - Photosynthesis, glycolysis, and TCA cycle
  - ATP Hydrolysis
  - Enzyme substrate interactions
  - Protein solubility
  - Protein Stability
- Binding Equilibria
- Reaction Kinetics

BIO 404 PHYSIOLOGY II

Objective:
An integrated systems-based examination of physiological processes in humans with a special emphasis on molecular mechanisms of pathophysiological and disease conditions in humans and experimental animal systems.

Approach:
The focus of this course will use the basic physiological principles learned in BIO 403 as a backdrop for exploring pathophysiological states and the molecular causes of human disease. We will explore these topics using as resources, a popular medical physiology textbook, primary literature reviews, and clinical/experimental case-reports. The course will involve lectures, class discussion, written papers, clinical/experimental case-studies, and invited speakers.

Textbook:
Human Physiology: An Integrated Approach, 4th ed., D. Silverthorn, Pearson Education / Benjamin-Cummings, 2007. ISBN: 0-8053-6849-3.

Prerequisites:
BIO 403 Physiology I or Graduate standing in Bioengineering, 1 year of Organic Chemistry, and Fundamentals of Biology for Bioengineers or equivalent.

Topics to be covered:

- Analysis of Complex Human Disease Genotypes/Phenotypes
- Molecular Physiology and Regulation of Fluid Homeostasis
- Physiological Disorders and Diseases of the Nervous System
- Molecular Physiology of Membrane Transport
- Metabolism and Energetics
- Hyperbaric and Hypobaric Physiology
- Endocrinology

BIO 505 MICROBIAL ECOLOGY

Objective:
Study of the diversity of microorganisms and the interrelationships between microorganisms and their environments. Emphasis is placed on aquatic ecosystems.

Prerequisites:
Graduate standing in Biology or Bioengineering; 1 year of Organic Chemistry; and Fundamentals of Biology for Bioengineers, or General Microbiology, or equivalent.

Topics to be covered:

- Microbial growth
- Microbial evolution and diversity
- Microbes in their Natural Habitats
- Methods in Microbial Ecology
- Biogeochemical cycles
- Wastewater treatment
- Biodegradation/Bioleaching
- Plant-microbe interactions
- Microbial Ecology of Disease
- Biological Weapons

BIO 523 ADVANCED MICROBIOLOGY

Objective:
Lectures, readings and discussions of current concepts in basic and applied microbiology, with emphasis on microbial metabolism and physiology.

Prerequisites:
Graduate standing in Biology or Bioengineering, 1 year of Organic Chemistry, and Fundamentals of Biology for Bioengineers or General Microbiology or equivalent.

Topics to be covered:

- Microbe Structure/function
- Microbial growth
- Membrane energetics
- Electron transport
- Oxygen toxicity
- ATP synthase
- Cytosolic Bioenergetics
- Central Metabolism
- Cell wall synthesis
- Photosynthesis
- Fermentation
- Anaerobic respiration
- Solute transport
- Protein export/secretion
- Genetic and growth regulation

BIO 524 ADVANCED CELL BIOLOGY

Objective:
Explores the structure and function of cells through their biochemical, molecular, and physiological activities.

Prerequisites:
Graduate standing in Biology or Bioengineering, 1 year of Organic Chemistry, and Fundamentals of Biology for Bioengineers or Cell Biology or equivalent.

Topics to be covered:

Review of

Cell Membrane
Cytoskeletal system: microtubule and cilia structure dynamics and effects
cytoskeletal microfilament structure and functions
Nuclear organization
Mitochondria: the power house of cell
Signal transport and sorting

Signal transduction pathways,
Stem Cells
Growth control, cancer, regeneration.
Cell death, necrosis, apoptosis
Cell Cycle
Cell Biology of Development and Disease

BIO 560 INTRODUCTION TO BIOINFORMATICS

Objectives:
BIO 460/560 is a dual-listed class, designed as a first course at the undergraduate and graduate levels in bioinformatics. The objective of the course is to introduce the student to the concepts and principles involved in analyzing molecular data (DNA and protein sequences), with hands-on exposure to some of the important software used and publicly available repositories (databases) of sequence and other relevant data. The course is structured to appeal to students from many disciplines, especially biology, computer science, chemistry, engineering, and mathematics since bioinformatics is a field that has, for the first time, brought about a real integration among all these hitherto diverse disciplines.

Prerequisites:
Graduate standing in Biology or Bioengineering and Fundamentals of Biology for Bioengineers or equivalent.

Topics:
- Database search tools
- Computational methods
  - DNA sequence homology
- RNA topology
- In silico promoter analysis
- Protein structure/folding models
- Microarray analysis
- Molecular Evolution

BIO 594 MOLECULAR BIOLOGY

Objective:
Introduction to the theory and practice of molecular biology techniques. Topics and laboratory exercises include the enzymatic manipulation of DNA and RNA, Southern and Northern blotting, library screening, DNA sequencing, DNA amplification, and gene promoter structure and function.

Prerequisites:
Graduate standing in Biology or Bioengineering, 1 year of Organic Chemistry, and Fundamentals of Biology for Bioengineers or Genetics or equivalent.

Topics to be covered:

- A general introduction to 3-D structures
- The higher organization of the genome
- Structure of DNA and telomeres
- DNA replication (prereplication, elongation, helicses, topisomerases)
- Transcription in prokaryotes
- Transcription in eukaryotes
- Splicing
- Modifications of mRNA
- Compartmentalization of transcription
- Protein synthesis
- The birth and death of proteins

CHM 427 MEDICINAL CHEMISTRY

Course Objective:
To provide the student with an understanding of how medicinal agents act in the body and how predictions of activity can be made with acknowledge of chemical structure.

Prerequisites:
1 year Organic Chemistry and 1 course in Biochemistry.

Topics:

- Physicochemical Properties in Relation to Biologic Action.
- Metabolic Changes of Drugs and Related Compounds.
- Drug Latentiation and Prodrugs.
- Combinatorial Chemistry.
- Antibacterial Antibiotics.
- Antiviral Agents.
- Antineoplastic Agents.
- CNS Depressants.
- CNS Stimulants.
- Adrenergic Agents.
- Cholinergic Drugs and Related Agents.
- Analgesic Agents.
- Anti-sense Drug Technology.
- Steroid Hormones.

CHM XXX ADVANCED BIOCHEMISTRY

Objective:
Combination of lecture and small group discussion. Each topic will get two meeting times dedicated to it. The first session will be a traditional lecture in which the topic is introduced, the background and biological significance is explained, and experimental methodologies used in that discipline are described. Following the lecture, students will be assigned 1 or 2 primary research articles to read that are relevant to the topic and a list of questions to answer for the second session. The second session will be a small group discussion that will focus primarily on how to read a research article and think critically about the authors' interpretation of data and the resulting conclusions. Strengths, weaknesses, and limitations of the experimental approaches will be discussed. Some of the papers will be chosen because they are fantastic examples of high-quality research, and some will be chosen because someone dropped the ball in a major way and it somehow slipped past both reviewers and editors.

Prerequisites:
Graduate standing in Chemistry, Biochemistry, Biology or Bioengineering and 1 year of Biochemistry.

Topics:

- High-resolution structural analysis of macromolecules
- Catalytic RNAs and splicing
- DNA replication
- Eukaryotic chromatin structure
- Enzyme kinetics
- Translational control in early embryonic development
- Protein trafficking through the nuclear envelope
- Signal transduction
- Viral-mediated membrane fusion
- Protein-protein interaction networks
- Eukaryotic cell cycle control

CME XXX BIOPRODUCT DESIGN

Objective:
Application of design process to products based on biological technology. Coverage of the entire design process from initial identification of product needs, to the generation and selection of product ideas, regulatory constraints, and culminating in the manufacture of a new product.

Prerequisites:
Graduate standing in Bioengineering.

Propsosed Text: Design of Biomedical Devices and Systems by Paul H. King and Richard C. Fries.

Topics to be covered:

- Introduction to Bio-Engineering Design
- Fundamental Design Tools
- Management, Documentation, and Reporting
- Product Documentation
- Product Development
- Human Factors Issues
- Biomaterials and Materials Selection
- Safety Engineering
- Prototyping and Testing
- Quality Control and Liability
- FDA Requirements
- Licensing, Patents, and Copyrights
- Case Study

CME 592 CHEMICAL AND BIOLOGICAL SENSORS

Objective:
A review of selected topics in chemical and biological sensors to complement laboratory analyses and online analyses in complex systems.

Prerequisites:
Graduate standing in Bioengineering and Fundamentals of Engineering for Bioengineers or equivalent.

Topics to be covered:

- Introduction to chemical sensors and biosensors
- Electrochemical sensors
- Molecular recognition
- Enzyme electrodes
- Device design
- Nanosensors and nanobiosensors
- Applications

CME XXX BIOSEPARATIONS

Objective:
This course will cover the selection and design of separation processes for biological material. Techniques include: filtration sedimentation, extraction, liquid chromatography and adsorption, precipitation, crystallization, drying.

Prerequisites:
Graduate standing in Bioengineering, Fundamentals of Biology for Bioengineers or equivalent, and Fundamentals of Engineering for Bioengineers or equivalent.

Topics to be covered:

- Review of Biomarcomolecules
- Analytical Techniques
- Cell Lysis and Floculation
- Filtration
- Sedimentation
- Extraction
- Liquid and Adsorption Chromatography
- Precipitation
- Crystallization
- Drying

ECE XXX BIOINSTRUMENTATION ENGINEERING

Objective:
Analysis of the technical components of bioinstrumentation for equipment design.

Prerequisites:
Graduate standing in Bioengineering.

Topics to be covered:

- Biosignal collection
  - Biopotentials and electrodes
  - Transducers and couplers
  - Data conditioning and transmission
- Signal processing in bioinstrumentation
  - Linear system theory
  - A / D conversion
  - Noise and filtering
  - Experiment in processing ECG data
- Bioimaging instrumentation
  - Optics
  - Ultrasonics
  - Waves
  - Magnetic imaging
  - CT
  - Experiment in ultrasonic imaging

ECE 563 DIGITAL IMAGE PROCESSING

Objective:
Two-dimensional signal processing theory and application to digital image processing with emphasis to applications in medical image processing. Image acquisition, enhancement, compression and analysis.

Textbook:
Digital Image Processing, 2nd ed., Gonzalez and Webb, Prentice Hall, 2002.

Prerequisites:
Graduate standing in Bioengineering.

Topics to be covered:

- Introduction to image processing and MATLAB essentials
- Image enhancement
- Image restoration
- Basics of color
- Morphological image processing
- Image segmentation
- Object recognition
- Medical image processing applications

ECE XXX DATABASE SYSTEMS FOR BIOINFORMATICS

Objective:
Methods to assist investigators in robust analysis of large database systems in support of bioinformatics.

Prerequisites:
Graduate standing in Bioengineering.

Topics to be covered:

- Entity-Relationship data model
- Relational Model Design
- Metadata
- Database data entry, query, and data export
- Databases
  - Protein
  - Sequence
  - Microarray and Proteomic
- Design of Biological Database Systems
- Data merging

MAT / MEE XXX SURFACE AND INTERFACE PERFORMANCE OF BIOLOGICAL MATERIALS

Objective:
Structure-property relationships of materials, chemistry of surfaces and interfaces, materials-tissue interactions, selection and design of materials for medical implant devices.

Prerequisites:
Graduate standing in Bioengineering.

Topics to be covered:

- Surface and interfacial properties of materials
- Surface characterization
- Protein adsorption
- Cell-material interactions
- Foreign body response
- *In-vitro* and *in-vivo* testing of biomaterials

PHY XXX BIOPHYSICS

Objective:
To provide students with a basic quantitative and analytical understanding of the physiological properties of biological phenomena and processes.

Prerequisites:
Graduate standing in Bioengineering and Fundamentals of Biology for Bioengineers or equivalent.

Topics to be covered:

- Introduction to biophysics
- Mass points, motion
- Dynamics: mass, acceleration, force, stress, pressure (cardiovascular system)
- Work, power energy
- Conservation laws
- Thermodynamics (of living systems)
- Physics and biological processes (membrane transport)
- Experimental and theoretical basis for phase boundaries (diffusion)
- Gas laws (respiratory system)
- Fluid dyamics (hemodynamics)
- Electrical charge (membrane dynamics)
- Magnetic fields (medicine)
- Electromagnetic waves
- Physical characterization of light (biosensors; optics)
- X-rays
- Radioactivity; radioactive isotopes; Nuclear medicine

CME 599 BIOENGINEERING THESIS

Objective:
This is a two course sequence to cover the research and thesis of the graduate student.

Prerequisites:
Graduate standing in Bioengineering and approval of thesis advisor.

Students will perform research under the guidance of faculty from the School of Engineering or the College of Arts and Sciences. Research will be written as a thesis and defended before a graduate committee represented by both the School of Engineering and the College of Arts and Sciences. Research is intended to be published in peer-reviewed journals.

CME 598 CAPSTONE PROJECT

Objective:
This is a single special problems course to be taken only as part of the non-thesis MS program. Students must submit a proposal and a final report.

Prerequisites:
Graduate standing in Bioengineering and approval of the program director.

Students will participate as a team working to solve an industrial or institutional problem. This will be a semester long course working on a problem from delivery of problem statement to design of a working solution with a prototype or supporting scale data to demonstrate effectiveness of the proposed solution. Students will be evaluated periodically towards the project goal through interim deliverables and milestone achievements. Project will culminate with a final report detailing the design, biological and engineering analysis, scale-up analysis, and supporting data. Students will also orally present the outcome of their project to classmates, faculty, and as applicable, local industry or institutions.

APPENDIX C: RESPONSE TO FEEDBACK ON THE PDP

Comments from Cleveland State University

Concern: The rationale does not really make clear what the end-result of the program would be. Would students continue on to further education in either engineering or in science? Would they move into industry? How would the proposed M.S. prepare students for either path?

Response: The proposed M.S. program would provide an educational basis to allow the students to either continue in academia in the pursuit of a doctorate degree or enter into industry. The courses have been selected to provide the students with a broad understanding of bioengineering and a deep educational basis within his/her selected emphasis area. Students have the option to pursue either a thesis masters in bioengineering or focus on an application of bioengineering in the capstone classes, the student has the flexibility to tailor his/her education toward his/her desired career aspirations.

Concern: The selection of departments needs more justification: e.g., Geology, for example, seems to be added for inclusiveness, rather than as a core need.

Response: Upon initial development of the program, Geology was a program that had potential to integrate into the Bioengineering framework, subsequent revisions do not explicit state Geology. No department will be excluded from participating in the MS in Bioengineering program if faculty research is applicable to the emphasis areas.

Concern: Given the small number of core and emphasis credits, the phase-in period seems slow, although later mention is made of catering primarily to part-time students, so perhaps this could be better integrated.

Response: It is anticipated that most students will initially be part time and will allow for phase in of the program. Phase in of full emphasis programs will be based in part on emphasis areas where there is greatest student interest.

Concern: The prospective enrollment figures need some justification.

Response: The enrollment data is based on enrollment in similar programs at the University of Dayton.

Concern: What distinction is planned between thesis and capstone project?

Response: The thesis option will be a research driven project culminating in the preparation and final defense of a thesis before a faculty committee. Research should be able to be published in peer-reviewed journals. The capstone course will apply the skills learned from the bioengineering curriculum to address an industrial or biotechnologically relevant problem from concept to design.

Suggestion: Given that course work prerequisites are specified, the specification of particular fields for the B.S. seems unnecessary.

Response: The B.S. degree requirement will generally cover many of the pre-requisites.

Suggestion: In the proposed program of study, biosystems is not readily definable. I suspect for other readers of the interdisciplinary program, short definitions of all four areas would be useful.

Response: The full proposal and required and elective courses for each emphasis describe the topics to be covered in each emphasis area.

Suggestion: The choice of home department seems fine, but some justification of the choice would help.

Response: The course is housed in chemical engineering, however, curriculum components will be advised by a multidisciplinary steering committee comprised of faculty from the SOE and CAS. Course offerings and scholarship activities will include SOE faculty and students from several other programs such as Mechanical & Aerospace Engineering, Electrical & Computer Engineering, Civil & Environmental Engineering, and Electro-Optics. Within the CAS, the Departments of Biology, Chemistry, Computer Science, Mathematics, and Physics will be involved in delivering courses, and advising/mentoring students in research projects or thesis.

Suggestion: What will be undertaken to make sure that the teaching faculty really are a cohort delivering a coherent program?

Response: The curriculum will be advised by a multidisciplinary steering committee comprised of faculty from the SOE and CAS. Many of the courses will be team taught. This approach is being defined this coming spring in the design and deliver of Transport Phenomena in Biological Systems being developed and taught by a faculty from SoE and one from CAS

Comment: The PDP provides justification on the need for the program at the University of Dayton, but it is not very convincing with respect to why the existing departmental and program structure is inadequate.

Response: The students entering the program can be from the Sciences or Engineering and many of the courses are team taught by faculty from both units. The emphasis of the program is multi-disciplinary. These require a structure of steering committee from both units. Having its own director gives the program leadership whose main focus is the program. Housing it in Chemical Engineering provides resources and stability.

Comment: The description of the “capstone project” is too general and does not allow us to evaluate its significance and its possible uniqueness compared to other Universities.

Response: The project will be a traditional project structure and does not have any uniqueness when compared to other similar courses at the University of Dayton or other institution. It is anticipated the course to be practical real world problems and would be multi-disciplinary.

Comment: In addition, the numbers for the expected enrollment are not – even briefly – justified. Finally, the fact that there is no need for new faculty members can be seen as, both, good (financially) and bad (essentially a re-structure of existing programs).

Response: This has been justified in the proposal based on the campus research focus area, our relationship with the Air Force Materials Laboratory and the BRAC realignment which is expected to bring a large number of professionals to this area.

Comment: A strong justification on the need for the program and for the expected enrollment is necessary. The Curriculum, as shown in the Appendix, raises some questions. For instance, although it is understandable why the course *Foundations of Biomaterials* is included in the Biomechanics area, it is not clear why the course *Foundations of Biomechanics* is not included in the Biomaterials area. Also, it seems that each of the four emphasis areas has two required courses related to some degree with this area and two more courses not really closely related to it. This can be confusing since not all four courses are what the PDP states as "specialized advanced study" courses.

Response: This has been addressed in the proposal.

Comments from Ohio State University

Comment: There is considerable overlap with other programs offered in the state. At Ohio State, the Biomedical Engineering graduate program includes substantial emphasis on biomechanics and biomaterials while the College of Medicine has a department, including a sizable research and educational component, of bioinformatics.

Response: The MS in Bioengineering program at UD will focus on applying bioscience and bioengineering principles and concepts to current areas of strength at UD, including materials, sensors, imaging, therapeutic devices and instrumentation. Our objective has been to define emphasis areas that complement our existing capabilities in the bioengineering field while minimizing the potential duplication with the other programs. For example, rather than emphasizing pharmaceutical or medical research, the proposed program will provide a formal curricular avenue in the previously mentioned areas. The bioinformatics program has been revised to more accurately represent it is bioengineering instrumentation, which will include biomimetics, biosensors, biphotonics, and bioinformatic data structures. As mentioned, OSU does not currently offer a non-thesis masters and the ability for UD students' to individualize their curriculum sets this program apart.

Comment: Evaluating only course titles (as that's all that was presented) there is some concern about the depth of the program, particularly since the students will be accepted into the program from an array of undergraduate majors. Course descriptions or syllabi might clarify this issue. Some of the focus areas might only be possible for students with specific backgrounds; e.g., a computer science major might be necessary to succeed in the bioinformatics track. It is also unclear whether the capstone project is one year-long project or two smaller, single-semester projects.

Response: Additional details of course topics are provided in this full proposal. The pre-requisites may require additional classes to be taken for participation in certain emphasis areas based upon individual course requirements. It is true that all students satisfying the broader entrance requirements may not meet individual course requirements. The capstone course will be a one semester project based upon industry topics with faculty assistance as needed.

Comment: One unique aspect of the program seems to be a plan to accommodate part-time students. The non-thesis option allows students to organize their class schedules and overall program without regard for research or funding constraints.

Response: This was a major consideration in developing the curriculum.

Comment: The decision to administer this interdisciplinary program within the Dept. of Chemical and Materials Engineering potentially creates autonomy issues. To have the necessary influence and be recognized as a peer by other department chairs, the program director should sit on the appropriate College-wide administrative committees. As a division-director beneath the chair of CME he/she will not have the same influence and bargaining

power as a department chair. Without that presence, the job of administering the Bioengineering program will be much more difficult and the program may be at risk as budgets constraints tighten.

Response: The Department of Chemical and Materials Engineering has high stakes in the success of this program and therefore the program will see significant support from the chair and the department. The growth of the program in the future could justify having its own department. The emphasis across the state is on combining programs to reduce administrative costs and allow sharing of facilities and resources.

Concern: Important administrative issues will need to be addressed. Who controls the program budget? Who will have control of the resources for faculty and staff salaries? Who will have the authority to enforce teaching schedules and program-related service tasks? What role will the director have in the faculty promotion and tenure process for faculty in other departments? What leverage will the bioengineering program have when the need arises to "re- allocate faculty with both the SOE and CAS to support new teaching responsibilities that will occur as the program matures and requires more advanced courses." Working these issue out in advance will help assure the continued viability of a new program that will need to compete for limited resources across two major administrative units.

Response: The university has very successful programs in similar situations. The Materials Engineering program is within the department with a program director and similar structure. The MAT program has been very successful. We have experience at starting multi-disciplinary programs such as Electro-optics program. If the program grows and would require its own chair, the university would consider a more autonomous structure.

Comment: The business plan requested in response to question 9 is insufficient. Specific support and a written memorandum of understanding among the administrative units involved (UD, SOE, CAS, departments) will help avoid later conflicts that could undermine the program.

Response: Similar programs in Electro Optics get contribution from many of the departments on campus. Not sure if they have an advisory council, but I am sure they have very synergistic working relationships. A memorandum of understanding should be considered by the advisory board.

Comment: Admission and program decision-making processes, including specific standards and protocols, will need to be developed. Student participation should be part of this process. Possible sources of student support need to be addressed. Participation of "community" faculty would capitalize on the resources in the Dayton area, add to the perspective of the program, and possibly open avenues for grant or contract support.

Response: These are very good suggestions and we will look into the use of adjunct "community" faculty to support the program academically, professionally, and financially.

Comments from Ohio University

Comment: Although the program proposal states that the proposed program "does not overlap in scope or objective with current biomedical engineering programs offered at other institutions in the state," the proposed program is virtually identical to the M.S. Biomedical Engineering program offered at Ohio University. That said, we do not see any potential conflicts with the Ohio University program

Response: The University of Dayton MS in Bioengineering does have some similarities with the Ohio University MS in Biomedical Engineering program in that both allow individualization of the curriculum. The UD program provides more structure by having established emphasis areas with predetermined required courses. Additionally, the UD capstone course option for a non-thesis MS in Bioengineering is an important difference between the two programs.

Comment: The PDP seems rather unfocused. Hopefully these comments will be helpful in preparation of the Full Proposal.

Response: Proposal has been revised to address areas of concern.

Comment: The PDP states that there will be 4 focus areas: Biomechanics, Biosystems, Biomaterials, Bioinformatics. This seems ambitious for a new program. Why these 4 areas? The full proposal should demonstrate that UD has a cohort of faculty members that have expertise in each of these areas (e.g. significant publications in peer-reviewed journals, issued patents and/or external funding for their research programs).

Response: The *vitae* of the faculty are presented in the full proposal. Additional faculty having a bioengineering focus have recently been hired in the Chemical Engineering and Mechanical and Aerospace Engineering departments. Additionally, a faculty search is underway for an open position in the Biology department with a preference for biosensor research.

Comment: On page 1, first paragraph, the authors state that the program "does not overlap in scope or objective with current biomedical engineering programs offered at other institutions in the state". Is this accurate? For example, a look at the Univ. of Toledo web site lists several faculty members that do research in Biomechanics/Biomaterials.

Response: It is true that researchers at a number of institutions study biomechanics/biomaterial and other related bioengineering topics. The program differs from the U Toledo program in its multidisciplinary focus integrating faculty from the SOE and CAS.

Comment: In the admission requirements the proposal states that they will require 1 year of biology and lab. This is vague -- does this mean any biology course and lab regardless of content?

Response: The biology lab requirement has been eliminated.

Comment: For bioinformatics, the emphasis is unclear. If it is management of genomics, proteomics, etc. information than the following is suggested: The physics prerequisite should be dropped in favor of adding requirements for discrete mathematics, matrix theory, analysis of algorithms, and theory of computation.

Response: The bioinformatic emphasis areas has been changed to bioengineering instrumentation to more accurately describe the curriculum.

Comment: It is unclear if the proposed degree will be a course-based masters or a research-based masters. Six hours of thesis is required and it appears that a capstone experience will be equivalent to the thesis (see top of page 2). If these are equivalent, perhaps the thesis should be a project. Will the students need to write and defend their thesis? Is work suitable for publication in a peer-reviewed journal a benchmark for an acceptable thesis?

Response: The capstone course will be an extensive project applying the principles of bioengineering. The thesis masters will be a research driven project in one of the participating MS in Bioengineering faculty research labs. It will culminate with a thesis and oral defense and produce work that is suitable for publication in peer-reviewed journals.

Comment: The proposal states that a program director will administer the operation of the program on a day-to-day basis. The assumed 25 students will create a major administrative burden. Are there plans for financial compensation and administrative assistance for the program director? Compensation and administrative support are necessary for running a top-tier program.

Response: Agree. The resources will be provided by the school and department to provide the necessary help for it to succeed.

Comment: The fact that BRAC will lead to 1000 new health and biomedical-related training and R&D jobs in the Dayton area by 2011 is a potentially compelling reason to initiate this program. Will these be jobs in biomechanics, biosystems, biomaterials, and bioinformatics? The full proposal will need to give further details on these employment opportunities. If this is “real”, it can be a very compelling case for the program and could be a main driver for how the program is developed. This would need to be detailed in the full proposal.

Response: The emphasis areas were selected because of either a strength on campus or a desire to develop that strength. This was arrived at by identifying the areas of expertise and research focus areas on campus. The emphasis area structure allows an adaptive program that focuses on the fundamentals with the required classes and flexibility and adaptability with the electives. If a new area of emphasis is deemed necessary or an area of interest need modification, this can be accomplished without compromising the fundamentals.

Comment: On page 3, first paragraph, the authors claim that their program is "distinctive in that it will have an integrated core of both engineering and science faculty who will participate…in the program" Is this truly distinctive within the state of Ohio?

Response: There are some similarities to other programs, however, the other programs are based out of a single department or a bio(medical) engineering department and are not the integrated approach taken at UD.

Comment: On page 3, second paragraph, the authors state "the University is committed to advancing the understanding of bioscience and bioengineering in order to turn out more graduates…" This would certainly help the program but no evidence is given and University commitment to the proposed MS Bioengineering program is unclear. The full proposal will need to provide tangible evidence of university commitment specific to the proposed new program.

Response: Two hires in the school of engineering this year have a strong background in this area. One has expertise in Biochemical Engineering, one in biomechanics. Recently, the chemical engineering department supported a faculty sabbatical in the area of biofluid mechanics. Resourses are being placed to develop the necessary courses and laboratories.

Comment: Near the end of page 3, the authors suggest that their program will be synergistic with Energy and the Environment. In what way? Specifically which proposed focus area(s) will be synergistic with this effort. If the energy and environment effort involves microbes and/or use of biomass as an energy source, it might be best supported by an emphasis area in cell and molecular engineering.

Response: The Bioprocess emphasis area will include research and curricula topics that address bioenergy and environmental applications. Dr. Comfort was recently hired in the chemical engineering department and one focus of his research is on application of sugar processing enzymes for bioethanol fermentation.

Comment: They anticipate that the majority of the students will be part-time. It is unclear how this has been taken into account in the design of the program. The full proposal will need to demonstrate how this fact has driven the overall design of the program.

Response: The program design allows for part-time students through the non-thesis masters option by taking the capstone course.

Comment: Will the students in the program be offered a stipend or will they be fee paying?

Response: Research and teaching assistantships will be available to full time students. Part time students are typically self paying.

Comment: What will be the source of the funds for the thesis projects? For example, assuming the projects involve supplies, how will these be paid for?

Response: Most research is supported by grants and contracts. Principal Investigators would be responsible for the research support.

Comment: The focus of the bioinformatics curriculum is unclear. If it is management and mining of genomic, proteomic etc. data than the following is suggested. If not, then a better descriptor should be considered or the proposers need to clarify what they mean by bioinformatics.

Response: The descriptor has been changed to Bioengineering Instrumentation.

Comment: On page 4, last paragraph, the proposal states: "After the first year of the program, we anticipate the need to re-allocate faculty within both the SOE and the CAS to support the new teaching responsibilities that will occur as the program matures and requires more advanced courses." Do the faculty and Deans of SOE and CAS support this? Full support of the Deans, department chairs and participating faculty are needed and the full proposal must provide sufficient evidence that this re-allocation of effort will actually occur.

Response: Already taking place with the hiring of a faculty member in biochemical engineering and one in biomechanics.

Comment: On the last lines of page 4, the authors suggest that they are collaborating with bio-medical imaging. The full proposal will need to relate this collaboration to one of the focus areas.

Response: Already address in the bioengineering instrumentation

Comment: Adding a new program with 25 students will require an increase in staff and possibly facilities.

Response: addressed earlier with reallocation of resources and faculty.

Comment: This (Projected and Additional Costs) appears to be in development.

Response: Details have been included in full proposal.

Comment: Appendix A lists all the courses. Which ones are new courses? A course like Bioengineering seems really broad. Are they anticipating that their students will come in with no bioengineering background? More details regarding each course will need to be provided in the full proposal.

Response: More detailed descriptions of the courses are listed in Appendix A.

Comments from University of Akron

Comment: The development of this program largely represents a reorganization of existing educational efforts at UD to develop an interdisciplinary training program. Current faculty's teaching efforts are to be reallocated and funding will be provided by the university.

Response: As detailed in the current proposal, additional part-time faculty will be hired to back-fill teaching responsibilities of full-time faculty participating in the MS in Bioengineering program. Additional faculty have been hired in chemical engineering and mechanical and aerospace engineering with the Bioengineering expertise and an additional position in the Biology department is open for a researcher in the Biosensor field.

Comment: As stated, this program is similar to the growing emphasis on interdisciplinary graduate programs in the state, such as UA's Integrated Bioscience (IB) PhD. However, the proposal clearly tries to distinguish itself by focusing on a small core of interdisciplinary areas. Furthermore, it intends to draw upon a different body of students than UA's program – mostly part-time, local students with a narrower range of backgrounds.

Response: The UD focus is on student's pursuing a master's degree and is unique from the University of Akron's IB program as stated.

Comment: Most of the curriculum will be provided through existing courses in engineering and the biological sciences. This is likely to cause some problems for students because it is unlikely that undergraduate engineering students will have the background necessary to undertake graduate level biology courses and vice versa. How will the program ensure that engineering students won't be "left behind" in an advanced biology course or that an engineering course won't be "dumbed down" to accommodate a biology student's lack of appropriate training in physics (only 1 year required)?

Response: To bridge the curriculum gap for incoming students, the introductory courses, "Fundamentals of Biology for Bioengineers" and "Fundamentals of Engineering for Bioengineers" are geared towards students with engineering and life science backgrounds, respectively. The entrance requirements were selected to ensure that students would satisfy course pre-requisites and be able to meet the demands of the curriculum.

Comment: I think that the program should be commended for its intention to develop truly interdisciplinary, team-taught classes and that this will offer a partial solution. In particular, the core starts with two different courses that seem specifically designed to address this problem – I just worry that a single course won't be enough. I suspect the overall emphasis on engineering courses will largely limit incoming students to those with engineering backgrounds.

Response: We truly hope that this is not the case as the introductory course "Fundamentals of Engineering for Bioengineers" is designed to develop fundamentals of engineering for non-engineering students.

Comment : The proposal doesn't see a need for additional facilities or staff. The current proposal makes it sound as though the faculty that will be involved largely fall within traditional disciplinary boundaries. Yet, for success, the program will require at least some faculty to reassess their research and develop new collaborations to support bioengineering. Do not underestimate the amount of time that faculty have to devote to develop truly integrative research. Do you have a plan to facilitate this transition in research focus?

Response: As indicated in the full proposal and previous responses, additional part-time faculty will be hired to back-fill courses associated with this program that full-time faculty will be teaching. Additionally, full-time faculty new hires will be considered for their research and ability to integrate within the Bioengineering program.

Comment: My major concern deals with calling this a graduate **engineering** degree program. The admissions requirements allow individuals without an appropriate undergraduate engineering degree to enroll. The list of prerequisites for non engineers include math, chemistry, physics and biology, but they do not include any of the core engineering courses necessary for understanding and successfully completing a graduate degree in an engineering discipline. In contrast, admission to our graduate BME degree program requires not only four semesters of mathematics, including calculus and differential equations, but also two semesters of classical physics, chemistry and at least five additional undergraduate engineering courses in one of three specialty areas (mechanics, materials or instrumentation/imaging). This leads one to question the depth of the graduate engineering course work cited in this Program Development Plan. I believe this proposal for a master's degree in bioengineering could be strengthened by ensuring that the potential students have the necessary undergraduate engineering core to successfully complete a graduate engineering degree.

Response: This program will be fashioned after the MS in Chemical Engineering for students with BS degrees in chemistry. This program requires that the students have all the physics and math including differential equations and have to take 5 undergraduate engineering classes in material and energy balances, transport phenomena, unit operations, and applied math. The graduate courses will have the necessary pre-requisites to ensure that the students have the proper engineering background, the engineering principles for non-engineers will provide some of the tools and then courses like transport phenomena in biological systems and thermodynamics and kinetics for biological systems will ensure that the fundamental engineering skills are developed further and applied to biological systems. The advisor might also need to suggest additional courses to make sure the proper tools are developed.

Comments from University of Cincinnati

Comment: It is indicated that the emphasis areas will include biomechanics, biosystems, biomaterials, and bioinformatics, and that the foundation of this program will be to support on-going research at UD in these emphasis areas. However, justification for these emphasis areas is not well supported by a detailed description of what is the on-going research at UD that requires this support. Several labs are referred to, but a more detailed list of opportunities for students would be welcome.

Response: A list of faculty *vitae* are included in the full proposal. Note the change in emphasis area descriptor from bioinformatics to bioengineering instrumentation.

Comment: They also indicate that the scope and objective of their program does not overlap with other engineering programs offered within the state, but certainly there emphasis areas are the scope and objective in many other programs. As an example, how will the bioinformatics program differ from similar programs at Ohio State University and the University of Cincinnati? How would biomechanics or biomaterials differ from programs in these areas at Wright State or at Case? A more detailed description of the unique nature of this degree in comparison to other programs would have been beneficial. Also a more detailed description of the research labs at UD which could support this program and its students both academically and financially would have been helpful. Several labs are mentioned in section 4, but how those labs fit into this program escapes me.

Response: The overall interdisciplinary nature of the program differentiates it from the programs at other universities. There will be some similarities in research and foci between university, but the ability of the student to individualize a program within an emphasis area distinguishes it from other programs. Faculty *vitae* are provided in the full proposal.

Comment: Further on in the program description it is indicated that there is a need for this program based on the recent impact of BRAC legislation in moving a large number of scientist into the Dayton area. This refers to the need to support the move of scientists to Wright Patterson Air Force base in the upcoming years. However, there is no documentation provided which supports this need. How many scientists and in what programs will be matriculating at UD as a result of this move? How will this need interface with the emphasis areas selected?

Response: As mentioned above:
The emphasis areas were selected because of either a strength on campus or a desire to develop that strength. This was arrived at by identifying the areas of expertise and research focus areas on campus. The emphasis area structure allows an adaptive program that focuses on the fundamentals with the required classes and flexibility and adaptability with the electives. If a new area of emphasis is deemed necessary or an area of interest need modification, this can be accomplished without compromising the fundamentals.

Comment: This proposal in general as it comes across more as filling the need of researchers at UD for students vs. filling the needs based on what these students might do once they finish. Further job justification for the need of this program for workforce development would be essential. Overall, the need is poorly justified or fragmented.

Response: Certainly there is a need for developing knowledge and expertise in the workforce for the emphasis areas described. These areas were chosen in existing areas of strength or desired areas of strength because that is where we can use our expertise to serve the students best

Comment: It is unclear what the College of Arts and Sciences gets out of this interdisciplinary program. Certainly, they will be doing a substantial part of the teaching in this program, but what benefits will they directly get from these students? Will students in this program be able to work in research labs in biology, biochemistry, chemistry, computer science, geology, math, or physics? Will the research projects involving the students be truly interdisciplinary between scientists from engineering and from Arts and Sciences? It would have been helpful to explain more the interdisciplinary meaning of this program. Is it interdisciplinary in education only, or will it advance interdisciplinary research at UD as well?

Response: Students will be able to perform research in CAS faculty labs. Thesis students will be required to have a faculty member from both the SOE and CAS on their committee.

Comment: The admissions requirements are excellent and well thought out. They avoid issues of taking students with an engineering degree and no biological experience as well as biological students with little or no computational or engineering experience.

Response: The goal is to allow both engineering and life science students to enter the program after meeting the entrance requirements.

Comment: There are no real issues with the curriculum with several exceptions.
a. Many of the course titles are self explanatory but many are not. For example, what will the core course in “Bioengineering” consist of? What constitutes advanced courses such as in “Advanced Biochemistry” or “Advanced Cell Biology”? A more detailed description of all of the courses would be useful in a full proposal.
b. While bioinformatics can mean many different things, it is unclear how and why these courses were selected? What will be the main focus of the bioinformatics? Genetics, proteomics, sequencing, information technology, large database management? A description of how courses such as sensors, biomimetics and biophotonics fits into a bioinformatics curriculum would be useful.

Response: A detailed list of course and syllabi are included in this proposal. As noted elsewhere, the bioinformatics emphasis area has been changed to Bioengineering Instrumentation.

Comment: How will the thesis and capstone activities be structured as interdisciplinary?

Response: Thesis research will be interdisciplinary by the availability of advisors from which students may chose. The Capstone course will be a long-term project, which will by its nature, incorporate aspects of biology and engineering into the proposed solution.

Comment: Again, why not allow students to enter into this program though A&S? This might be more interdisciplinary.

Response: The decision was made to house the program in the school of engineering. The final degree will be a MS of Bioengineering and therefore, entrance to the program is through the school of engineering.

Comment: What data justifies their expected enrollment success? These programs should be expected to provide data that back up their expectations with realistic numbers.

Response: The enrollment numbers, as stated in previous responses, are based upon start-up of other programs in the university.

APPENDIX D: CURRENT FACULTY VITAE

APPENDIX E: FINANCIAL ANALYSIS