I welcome you to our undergraduate program.

The mission of our program is to ensure students have the skills to succeed professionally by providing them with an academically rigorous, design-oriented, and medically focused program that emphasizes problem-solving, core and technical competencies, leadership, communication, and ethics.

We fulfill this mission through a unique “2 + 2” training model wherein students enter the program through a Pre-Bioengineering pathway, which takes place on the downtown Denver campus, and then proceed to the professional preparation component by applying for the Major, which takes place at the Anschutz Medical Campus. This program of study allows students to complete General Education and pre-Major core classes first and to build on these lessons through the bioengineering core courses, which combine advanced engineering and design topics with clinical applications. Having the core courses taught at the medical campus is a particularly unique component of our program. The major classes, the presence of the major teaching hospitals in Colorado including the University Hospital, the Children’s Hospital of Colorado, and the soon to be completed VA Hospital ensures that students will have multiple opportunities to interact with, learn from, and discuss research and technology with practicing clinicians and surgeons. In addition to the technical competencies, each class also emphasizes professional competencies such as communication, ethics, teamwork and leadership.

In addition to classes, we plan to offer several opportunities for you to enhance your undergraduate experience and help prepare you for your post-graduation ambitions. For example, we will offer summer research experiences on the medical campus; these provide opportunities to work in research labs or clinical environments. We will also offer clinical internships at specific imaging or clinical analysis labs, which provide opportunities to learn about how a particular technology (ultrasound imaging; mass spectrometry; etc.) is used in the clinical setting. Lastly, the Fitzsimons Biosciences Park, next to the medical campus, houses many biomedical companies; internship opportunities at these and other companies allow students to gain practical work experience and expand professional networks.

I urge you to explore the multiple opportunities available to you in this unique cross-campus program. Our professors, researchers, and staff are committed to your success. Since our program is new, I also urge you to let us know what works and what can be improved; this is your program and your feedback will help us make your experience as enriching and rewarding as possible, professionally and personally. For example, we will be building new teaching labs and community space on the medical campus as part of our program expansion. As a member of the bioengineering community at UC Denver, you will have the opportunity to help us design these spaces to best serve your needs. Your input is important since after all you will be the ones working and studying in these areas. Student feedback has been tremendously important in helping shape our graduate program to best meet the needs of our graduate students, and I want to make sure this happens for our undergraduate program as well.

Again, I welcome you into a field of study that will be challenging yet highly rewarding. Bioengineers command many leadership positions in industry, medicine and research. We look forward to helping you accomplish your goals.

Robin Shandas
Professor and Chair

2
Bioengineering
1. Description of Program

Bioengineering combines the mathematical and physical sciences with engineering principles to study biology, physiology, medicine, behavior, and health. Bioengineering is emerging as a leading engineering discipline at the interface of clinical sciences, basic sciences, and engineering. Bioengineers solve major problems in biology and medicine by applying established principles in the physical sciences and engineering. Over the last two decades, bioengineers have improved our quality of life by advancing basic research, developing new clinical applications, and designing useful assistive technologies. For example, highly precise imaging techniques have been developed to pinpoint cerebral areas relating to specific cognitive functions; advanced metal and polymer technologies have been harnessed to create new generations of medical prosthetics; advances in computational and experimental techniques have allowed exploration of biological structure-function relationships at multiple scales from the molecular level to whole organism; novel multi-functional devices that combine advances in chemistry, optics, mechanics, and electronics have been created to diagnose and treat disease; biomaterials advancements have led to the use of stem cells as a medium for controlled tissue construction, as well as the development of artificial bones, hearts, and other organs.

Bioengineering encompasses a wide range of disciplinary and application areas. The Biomedical Engineering Society (BMES) recognizes bioinstrumentation, biomaterials, biomechanics, cellular, tissue and genetic engineering, clinical engineering, medical imaging, orthopedic surgery, rehabilitation engineering, and systems physiology as established specialty areas in Bioengineering.

The Department of Bioengineering at the University of Colorado Denver was founded in 2010 as a new academic program that spans the College of Engineering and Applied Science and the University of Colorado Anschutz Medical Campus. The mission of the Department is to improve human health through the application of engineering principles, ideas, methods, and inventions to solve important clinical problems. The Department fulfills this mission by providing opportunities for instruction, research, and service in bioengineering to faculty, students, and residents of Colorado and the Greater Rocky Mountain region.

Research and instruction in Bioengineering at the University of Colorado Denver focuses on the application of engineering principles to the design, analysis, construction, and manipulation of biological systems and biomedical technologies as well as on the discovery and application of new engineering principles and technologies inspired by the properties of biological systems. Current areas of research and instruction include: biomedical devices; musculoskeletal prosthetics; biomechanics; polymer biomaterials; medical imaging and diagnostics; and cell and tissue engineering. Emerging areas of focus include: synthetic biology; systems biology; biomedical computation and modeling; biomedical nano- and micro-scale systems and fabrication; and environmental bioengineering.

2. Basic Design of the BS Bioengineering Program

The program will offer a Bachelor of Science (BS) degree in Bioengineering (BS-BIOE). The program will provide a rigorous, multidisciplinary education through a curriculum that integrates the three foundational disciplines of bioengineering: (1) biological, chemical and physical sciences; (2) engineering science and mathematics; and (3) clinical medicine. Graduates from this program are expected to become leaders and innovators in the bioengineering profession.
Students applying to the program must select Pre-Bioengineering (Pre-BIOE) as their “Field of Study” in the online application. If you are admitted to the Pre-BIOE program you will enroll in the core curriculum courses, which are offered at the Denver campus.

Students in Pre-Bioengineering must apply to advance to Major status in Bioengineering. The earliest time period to apply for Major status will be in Spring 2014 (specific deadline to be announced). Admittance to the Major in Bioengineering will be granted to students who have successfully completed all Pre-Bioengineering prerequisites and who meet the program’s selection criteria. All Major courses, which will be taught at the Anschutz Medical Campus, will not be available until Fall 2015.

Students entering the program as first year students and without any advanced college credits will be expected to take 56 credits in Pre-Bioengineering Core and 24 credits in General Education Core at the Denver Campus. This training is complimented by 48 credits in the upper-level Bioengineering Major and track specialization courses at the Anschutz Medical Campus.

Students admitted into major status in Fall 2015, will choose one of two proposed tracks of study:

A. Biomedical Devices and Biomechanics Track
   This track will prepare students for employment and/or graduate research in the design and fabrication of medical devices or in the analysis of physiologic function using principles of mechanics, mass- or heat-transfer, or fluid dynamics. Application areas for work under this track include design of musculoskeletal, cardiovascular, and other prosthetic devices; development of treatment methods such has thermal ablation systems; and development of methods to characterize properties of soft and hard tissues. This track will also prepare students for graduate research in a specialty where the methods of engineering and computational mechanics are applied to understand the function of bones, joints, and muscles, and for the design of artificial joint replacements.

B. Imaging Instrumentation and Diagnostics Track
   This track prepares students for employment and/or graduate research in the design, development, and application of electronics and imaging techniques to develop devices used in diagnosis and treatment of disease. Imaging is an essential component of the modern physician’s arsenal of diagnostics. Indeed, evaluation of complex diseases relies heavily on imaging techniques. Bioengineers play a unique role in this field in that they design new imaging methods, extract additional information from current imaging or diagnostic procedures through the thoughtful application of mathematical analysis, and generate reasoned approaches to regulations in medical imaging. Medical imaging combines knowledge of physical phenomena such as sound, radiation, magnetism, and light with high-speed electronic data processing, analysis, and display to generate an image.

Each of the two tracks will provide students with the basic scientific knowledge and engineering tools necessary for employment in the bioengineering and biomedical professions. Students will also be prepared for graduate study in bioengineering, medicine, and other health sciences, or in complementary areas such as law or business. Note that the UC Denver Bioengineering program is expanding rapidly, and other tracks are anticipated to be added as additional faculty are recruited over the next few years. Please consult the Pre-Bioengineering advisor for further information.
3. Student Learning Goals
The BS-BIOE degree will prepare students for careers in the biomedical industry, in hospital, government, or academic research labs, in regulatory agencies such as the FDA, and for further education in graduate school, medical school, or other advanced health sciences program. As stated above, the program is designed so that students who wish to enter medical school can fulfill pre-med requirements through the addition of one extra course.

The program’s student learning goals are derived from the “Criteria for Accrediting Engineering Programs, 2012-13” set by the Accreditation Board for Engineering and Technology (ABET). The program will document the eleven (a through k below) student outcomes that define what the students should know and be able to do by the time of graduation:

a) an ability to apply knowledge of mathematics, science, and engineering
b) an ability to design and conduct experiments, as well as to analyze and interpret data
c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
d) an ability to function on multidisciplinary teams
e) an ability to identify, formulate, and solve engineering problems
f) an understanding of professional and ethical responsibility
g) an ability to communicate effectively
h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
i) a recognition of the need for, and an ability to engage in life-long learning
j) a knowledge of contemporary issues
k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

As students progress through the Pre-bioengineering curriculum, they will acquire these competencies, which will be measured uniquely throughout each course. Students achieve all eleven learning goals accumulatively and repeatedly as they progress toward the BS Bioengineering degree. By experiencing a genuine progression with reiterations from basic proficiency in the Pre-Bioengineering Core to advanced proficiency in the Bioengineering Major, graduates will be able to demonstrate a broad range of understanding in mathematics, life science, and engineering as well as the specific mastery of bioengineering competencies.

4. Student Responsibility / Maintaining Good Standing in the Program
Students in Pre-Bioengineering must maintain a cumulative grade point average of 3.0. Students who have achieved a GPA of 3.00 or above in Pre-Bioengineering may apply to the Bioengineering Major after taking all prerequisite courses. Students with a GPA below 3.00 in Pre-Bioengineering may be provisionally admitted into the Major in Bioengineering pending space availability. Students who do not meet these requirements will consult with a BIOE undergraduate advisor to identify an alternative major in engineering or basic sciences. Students in the Bioengineering Major must maintain a cumulative grade point average of 2.0 and a course GPA of 2.0 in BIOE coursework.

Students who fail to maintain a cumulative grade point average of 2.0 in any semester will be allowed to continue their studies in probationary status during the following semester. Students on probationary status for two consecutive semesters will face suspension from the university. The program will follow
the university’s policies on probation and suspension, and the university’s policies on graduation, graduation honors and other recognitions.

5. Core Curriculum

A. Courses in Pre-Bioengineering (56 credit hours)
Students will complete all of these courses before they may apply for Bioengineering Major status. Credit for some of these courses may be achieved through high school Advanced Placement (AP) coursework and exams or courses from other institutions. Please consult the Pre-Bioengineering Advisor for further information.

Mathematics (16 credit hours):
- MATH 1401–Calculus I (4)
- MATH 2411–Calculus II (4)
- MATH 2421–Calculus III (4)
- MATH 3195–Differential Equations (4)

Biology (8 credit hours):
- BIOL 2051–General Biology I (3)
- BIOL 2071–General Biology Laboratory I (1)
- BIOL 2061–General Biology II (3)
- BIOL 2081–General Biology Laboratory II (1)

Chemistry (14 credit hours):
- CHEM 2031–General Chemistry I (3)
- CHEM 2038–General Chemistry Laboratory I (1)
- CHEM 2061–General Chemistry II (3)
- CHEM 2068–General Chemistry Laboratory II (2)
- CHEM 3411–Organic Chemistry I (4)
- CHEM 3418–Organic Chemistry Laboratory I (1)

Physics (10 credit hours):
- PHYS 2311–General Physics I (4)
- PHYS 2321–General Physics Laboratory I (1)
- PHYS 2331–General Physics II (4)
- PHYS 2341–General Physics Laboratory II (1)

Bioengineering (8 credit hours):
- BIOE 1010–Bioengineering Design and Prototyping I (2)
- BIOE 1020–Bioengineering Design and Prototyping II (2)
- BIOE 2010–Computational Methods in Bioengineering I (2)
- BIOE 2020–Computational Methods in Bioengineering II (2)

B. Courses in the Major Bioengineering Core (36 Credit Hours)
Students admitted into the Bioengineering Major will undertake the Major Bioengineering core courses regardless of the track they choose. All BIOE Major core classes will be taught at the
Anschutz Medical Campus. These classes build upon pre-major courses and provide the professional preparation component of instruction in Bioengineering. This instruction includes a year-long laboratory course, significant design experiences, and disciplinary subjects. **All students must take the following 12 courses (36 credit hours):**

- BIOE 3010 – Cell Biology for Engineers (3)
- BIOE 3011 – Cell Biology for Engineers Laboratory (3)
- BIOE 3015 – Physiology for Bioengineers (3)
- BIOE 3020 – Bioengineering Laboratory I (3)
- BIOE 3021 – Bioengineering Laboratory II (3)
- BIOE 3025 – Statistics for Bioengineers (3)
- BIOE 3030 – Biomechanics I (3)
- BIOE 3035 – Biomaterials I (3)
- BIOE 3040 – Bioengineering Design I (3)
- BIOE 4010 – Biomedical Instrumentation I (3)
- BIOE 4015 – Bioengineering Design II (3)
- BIOE 4020 – Senior Design Project (3)

**Curriculum Description and Assessment Process**

**Program Requirements**

The BS-BIOE degree comprises 3 core areas, supplemented by elective courses based on one of two tracks which the student chooses to pursue: The three core areas are: (1) the Pre-Major Core, which includes a Science and Mathematics Core; (2) the General Education Core; (3) Major Bioengineering Core. In addition, students will choose between the two Bioengineering tracks. Together these 3 core areas and your specialty track will define your program.

**C. Courses in the Bioengineering Tracks (12 Credit Hours)**

At present, the BS BIOE contains two track specializations:

1. Biomedical Devices and Biomechanics, and
2. Imaging Instrumentation and Diagnostics

Courses in these tracks will be taught at the Anschutz Medical Campus and expansion of specialties will grow with the department and recruitment of new faculty. Our tracks will provide students with a more advanced understanding of specialized areas in Bioengineering. Students must take a **minimum of 12 credit hours** of the courses in these tracks. **A minimum of 6 credit hours must be satisfied by courses offered by the Department of Bioengineering (BIOE XXXX), and a minimum of 6 credit hours must be satisfied by courses at the 3000 level or above.** With the approval of the Bioengineering Major undergraduate advisor, who will ensure that students have completed all pre-requisites, students may choose from the following courses (other courses may be substituted with prior approval of the BIOE undergraduate advisor):

**Biomedical Devices and Biomechanics Track**

- BIOE 3045 – Biomechanics II Advanced BioMechanics (3)
- BIOE 4025 – Biotransport and Heat Transfer (3)
- BIOE 4030 – Finite Element Analysis for Bioengineers (3)
- BIOE 4035 – Biomaterials II - Design of Biomaterials (3)
- BIOE 4420/5420 – Polymer Biomaterials (3)
BIOE 4045 – Mass Transport in Physiological Systems
BIOE 4073/5073– Neural interfaces and Biomechanics
BIOE 4046/5046– Advanced Matlab for Lifescientists and Engineers
BIOE 4420/5420– Animal Methods for Bioengineers
BIOE 4065/5065 – Biofluid Dynamics

**Imaging Instrumentation and Diagnostics Track**
BIOE 3050–Biomedical Signals and Systems (3)
BIOE 3055–Design of Biomedical Electronics (3)
BIOE 4070–Introduction to Biomedical Imaging (3)
BIOE 4075–Biophotonics (3)
BIOE 4080/5080– Lasers in Medicine (3)
BIOE 4046/5046– Advanced Matlab for Life Scientists and Engineers
BIOE 4420/5420– Animal Methods for Bioengineers
BIOE 4090/5090 – Biomedical Imaging II
BIOE 4092/5092 – Biomedical Optics (with lab)
BIOE 4095/5095 – Acquisition and Analysis of Physiological Signals

**C. Additional Courses in the General Education Core (24 credit hours)**
Students must satisfy the core curriculum requirements including **8 courses (24 credit hours)** distinct from the Math and Science requirements, as described in the Core Curriculum General Education. These core curriculum courses from will be selected from the Intellectual Competencies, Knowledge Areas, International Perspectives and Cultural Diversity areas. BIOE students may receive college credit for several General Education core courses through Advanced Placement.

**Hours required to graduate = 128**
This plan assumes that a student enters without advanced placement credits and takes 128 course credit hours (128 total).

### First Year 2013-2014

<table>
<thead>
<tr>
<th>Fall 2013 (17 Credits)</th>
<th>Spring 2014 (18 Credits)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 1401–Calculus I (4)</td>
<td>MATH 2411–Calculus II (4)</td>
</tr>
<tr>
<td>CHEM 2031–General Chemistry I (3)</td>
<td>CHEM 2061–General Chemistry II (3)</td>
</tr>
<tr>
<td>CHEM 2038–General Chemistry Lab I (1)</td>
<td>CHEM 2068–General Chemistry Lab II (2)</td>
</tr>
<tr>
<td>BIOL 2051–General Biology I (3)</td>
<td>BIOL 2061–General Biology II (3)</td>
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<tr>
<td>BIOL 2071–General Biology Lab I (1)</td>
<td>BIOL 2081–General Biology Lab II (1)</td>
</tr>
<tr>
<td>BIOE 1010–Bioengineering Design and Prototyping I (2)</td>
<td>BIOE 1020–Bioengineering Design and Prototyping II (2)</td>
</tr>
<tr>
<td>ENGL 1020–Core Composition I (3)</td>
<td>ENGL 2030–Core Composition II (3)</td>
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### Sophomore Year 2014-2015

<table>
<thead>
<tr>
<th>Fall 2014 (18 Credits)</th>
<th>Spring 2015 (18 Credits)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 2421–Calculus III (4)</td>
<td>MATH 3195–Differential Equations (4)</td>
</tr>
<tr>
<td>CHEM 3411–Organic Chemistry I (4)</td>
<td>BIOE 2020–Computational Methods in Bioengineering</td>
</tr>
<tr>
<td>CHEM 3418–Organic Chemistry Lab I (1)</td>
<td>BIOE 2020–Computational Methods in Bioengineering</td>
</tr>
<tr>
<td>PHYS 2311–General Physics I (4)</td>
<td>PHYS 2331–General Physics II (4)</td>
</tr>
<tr>
<td>PHYS 2321–General Physics Lab I (3)</td>
<td>PHYS 2341–General Physics II Lab (1)</td>
</tr>
<tr>
<td>BIOE 2010–Computational Methods in Bioengineering Research(2)</td>
<td>GENERAL ED CORE (3)</td>
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<td>GENERAL ED CORE (3)</td>
<td>GENERAL ED CORE (3)</td>
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### Junior Year 2015-2016

<table>
<thead>
<tr>
<th>Fall 2015 (15 Credits)</th>
<th>Spring 2016 (15 Credits)</th>
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</thead>
<tbody>
<tr>
<td>BIOE 3010 –Cell Biology for Engineers (3)</td>
<td>BIOE 3021–Bioengineering Lab II (3)</td>
</tr>
<tr>
<td>BIOE 3011 –Cell Biology for Engineers Lab (3)</td>
<td>BIOE 3015–Physiology for Bioengineers (3)</td>
</tr>
<tr>
<td>BIOE 3020–Bioengineering Lab I (3)</td>
<td>BIOE 3035–Biomaterials I (3)</td>
</tr>
<tr>
<td>BIOE 3025 –Statistics for Bioengineers (3)</td>
<td>BIOE 3040–Bioengineering Design I (3)</td>
</tr>
<tr>
<td>GENERAL ED CORE (3)</td>
<td>GENERAL ED CORE (3)</td>
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</tbody>
</table>

### Senior Year 2016-2017

<table>
<thead>
<tr>
<th>Fall 2016 (15 Credits)</th>
<th>Spring 2017 (12 Credits)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIOE 4015–Bioengineering Design II (3)</td>
<td>BIOE 4020–Senior Design Project(3)</td>
</tr>
<tr>
<td>BIOE 3030–Biomechanics I (3)</td>
<td>BIOE 4010–Biomedical Instrumentation I (3)</td>
</tr>
<tr>
<td>BIOE 4xxx–[Track Elective] (3)</td>
<td>BIOE 4xxx–[Track Elective] (3)</td>
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<tr>
<td>BIOE 4xxx–[Track Elective] (3)</td>
<td>BIOE 4xxx–[Track Elective] (3)</td>
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<tr>
<td>GENERAL ED CORE (3)</td>
<td>GENERAL ED CORE (3)</td>
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Bioengineering
7. Bioengineering Specialty Areas

**Bioinstrumentation** is the application of electronics and measurement techniques to develop devices used in diagnosis and treatment of disease. Examples of bioinstrumentation include systems to measure and analyze heart signals (EKG), brain signals (EEG, MEG), muscular signals (myograms), and measurements of cellular signals.

**Biomaterials** include both living tissue and artificial materials used for implantation. Understanding the properties and behavior of living material is vital in the design of implant materials. The selection of an appropriate material to place in the human body may be one of the most difficult tasks faced by the biomedical engineer. Certain metal alloys, ceramics, polymers, and composites have been used as implantable materials. Biomaterials must be nontoxic, non-carcinogenic, chemically inert, stable, and mechanically strong enough to withstand the repeated forces of a lifetime. Newer biomaterials even incorporate living cells in order to provide a true biological and mechanical match for the living tissue.

**Biomechanics** applies classical mechanics (statics, dynamics, fluids, solids, thermodynamics, and continuum mechanics) to biological or medical problems. It includes the study of motion, material deformation, flow within the body and in devices, and transport of chemical constituents across biological and synthetic media and membranes. Progress in biomechanics has led to the development of the artificial heart and heart valves, artificial joint replacements, as well as a better understanding of the function of the heart and lung, blood vessels and capillaries, and bone, cartilage, intervertebral discs, ligaments and tendons of the musculoskeletal systems.

**Cellular, Tissue and Genetic Engineering** involve more recent attempts to attack biomedical problems at the microscopic level. These areas utilize the anatomy, biochemistry and mechanics of cellular and subcellular structures in order to understand disease processes and to be able to intervene at very specific sites. With these capabilities, miniature devices deliver compounds that can stimulate or inhibit cellular processes at precise target locations to promote healing or inhibit disease formation and progression.

**Clinical Engineering** is the application of technology to health care in hospitals. The clinical engineer is a member of the health care team along with physicians, nurses and other hospital staff. Clinical engineers are responsible for developing and maintaining computer databases of medical instrumentation and equipment records and for the purchase and use of sophisticated medical instruments. They may also work with physicians to adapt instrumentation to the specific needs of the physician and the hospital. This often involves the interface of instruments with computer systems and customized software for instrument control and data acquisition and analysis. Clinical engineers are involved with the application of the latest technology to health care.

**Medical Imaging** combines knowledge of a unique physical phenomenon (sound, radiation, magnetism, etc.) with high speed electronic data processing, analysis and display to generate an image. Often, these images can be obtained with minimal or completely noninvasive procedures, making them less painful and more readily repeatable than invasive techniques.

**Orthopedic Bioengineering** is the specialty where methods of engineering and computational mechanics have been applied for the understanding of the function of bones, joints and muscles, and for the design of artificial joint replacements. Orthopedic bioengineers analyze the friction, lubrication and wear characteristics of natural and artificial joints; they perform stress analysis of the musculoskeletal system; and they develop artificial biomaterials (biologic and synthetic) for replacement of bones, cartilages, ligaments, tendons, meniscus and intervertebral discs. They often perform gait and motion analyses for
sports performance and patient outcome following surgical procedures. Orthopedic bioengineers also pursue fundamental studies on cellular function, and mechano-signal transduction.

**Rehabilitation Engineering** is a growing specialty area of biomedical engineering. Rehabilitation engineers enhance the capabilities and improve the quality of life for individuals with physical and cognitive impairments. They are involved in prosthetics, the development of home, workplace and transportation modifications and the design of assistive technology that enhance seating and positioning, mobility, and communication. Rehabilitation engineers are also developing hardware and software computer adaptations and cognitive aids to assist people with cognitive difficulties.

**Systems Physiology** is the term used to describe that aspect of biomedical engineering in which engineering strategies, techniques and tools are used to gain a comprehensive and integrated understanding of the function of living organisms ranging from bacteria to humans. Computer modeling is used in the analysis of experimental data and in formulating mathematical descriptions of physiological events. In research, predictor models are used in designing new experiments to refine our knowledge. Living systems have highly regulated feedback control systems that can be examined with state-of-the-art techniques. Examples are the biochemistry of metabolism and the control of limb movements.

8. Undergraduate Core and Track Electives

**BIOE 1010 and 1020 – Bioengineering Design and Prototyping I and II**  
*Pre-Bioengineering Core Course, 2 credit hours each.*  
Bioengineering applies engineering principles, inventions, ideas and analyses to the solution of important problems in the human biomedical and health science area. The purpose of this course is to introduce students to engineering skills important for bioengineers, and to provide an introduction to the careers in Bioengineering. This course first provides an overview of the disciplinary topics in mechanical, electrical and chemical engineering that are useful for bioengineers, as well as topics in computer science and programming, materials science, chemistry, anatomy, physiology, cell biology and genetics that bioengineers deal with every day.

The main portion of the course is devoted to using computer assisted design (CAD) and prototyping to learn human anatomy, biomedical device design and principles of design optimization. This design-based course forms the cornerstone component of the design-based curriculum.

**BIOE 2010 and 2020 – Computational Methods in Bioengineering I and II**  
*Pre-Bioengineering Core Course, 3 credit hours.*  
Introduction to scientific computing to solve engineering problems with particular emphasis on biological problems. The student will consider problem identification, algorithmic design, and solution using appropriate computational tools such as MATLAB. Students will define computational problems in Bioengineering, formulate solutions as algorithms, translate algorithms into a computational tool, use these tools for program design and development, and document the design and use of appropriate software components and graphical representation.

**BIOE 3015 – Physiology for Bioengineers**  
*Major Core Course, 3 credit hours.*  
This course provides a thorough introduction to application of Bioengineering principles to the study of human physiology. Topics include development of models to evaluate structure-function relationships
at multiple scales, analysis of how disease develops from molecular to organism, and an introduction to
the various physiological systems of the human body.

**BIOE 3020 and 3021–Bioengineering Laboratory I & II**  
*Major Core Course, 3 credit hours each.*  
This course provides core laboratory instruction in fundamental topics in experimental Bioengineering.  
These include methods for cell and tissue culture, assessment of host-material interactions, evaluation of biocompatibility, design and assembly of bioinstrumentation such as sensors, EKG and EEG systems,  
data acquisition and analysis, soft and hard tissue testing, simple imaging techniques, introduction to experimental biology techniques, in vivo and in vitro diagnostics, and introduction to histopathology.

**BIOE 3025–Statistics for Bioengineers**  
*Major Core Course, 3 credit hours.*  
This course provides an introduction to the fields of experimental uncertainty, engineering and medical statistical analysis, including the development of statistically powered clinical or biomedical studies.

**BIOE 3030–Biomechanics I**  
*Major Core Course, 3 credit hours.*  
This course provides an introduction to the static and dynamic mechanics of solids with applications to biomedical engineering and the understanding of physiologic function. We emphasize the three essential features of all mechanics analyses, namely: (a) the geometry of the motion and/or deformation of the structure, and conditions of geometric fit, (b) the forces on and within structures and assemblages; and (c) the physical aspects of the structural system (including material properties) which quantify relations between the forces and motions/deformation. This course will provide students with an awareness of various responses exhibited by materials (tissue, bones, etc.) when subjected to mechanical and thermal loadings, as well as an introduction to the physical mechanisms associated with design-limiting behavior of engineering materials, especially stiffness, strength, toughness, and durability as applied to biomedical devices and structures.

**BIOE 3035–Biomaterials I**  
*Major Core Course, 3 credit hours.*  
This course provides an introduction to the field of biomaterials. It covers host-tissue interactions and biocompatibility, introduction to materials used for medical devices, regulatory standards governing biomaterials, and an introduction to tissue engineering.

**BIOE 3040–Bioengineering Design I**  
*Major Core Course, 3 credit hours.*  
This is the beginning of a 3 course sequence that ends with the senior design project and is intended to introduce concepts of classical engineering design and how these concepts can be applied to the field of biomedical device and technology design.

**BIOE 3045–Biomechanics II Advanced BioMechanics**  
*Track Elective, 3 credit hours.*  
This course extends concepts studied in Biomechanics I into more advanced analysis, modeling and characterization of mechanical and fluid dynamic principles as applied biomedical and physiologic problems.
BIOE 3050–Biomedical Signals and Systems
Track Elective, 3 credit hours.
In this course, the student will be introduced to analysis of analog and digital biomedical signals and physiological systems. Subjects considered include: ordinary differential equations, difference equations, Fourier Series expansions, Laplace and Fourier transforms, linear time invariant systems, impulse response. Analysis of signals and systems using computer programs including their shortcomings are considered. Introduction to Advanced Engineering Mathematics I or its equivalent is required.

BIOE 4010–Biomedical Instrumentation I
Major Core Course, 3 credit hours.
This course focuses on the design and analysis of diagnostic and imaging instrumentation systems such as EKG and EEG sensors, ultrasound, optical and x-ray imaging systems, and signal and image analysis techniques.

BIOE 4015–Bioengineering Design II
Major Core Course, 3 credit hours.
This course continues from Bioengineering Design I, with focus on developing student-generated design ideas that are developed further into prototypes and pipelined into the Senior Design Project.

BIOE 4020–Senior Design Project
Track Elective, 3 credit hours.
A capstone course intended to bring students’ design projects that were begun in the prior 2 design courses to completion.

BIOE 4025–Biotransport and Heat Transfer
Track Elective, 3 credit hours.
This course focuses on the analysis of biomedical and biological systems using concepts of transport and heat transfer. Examples around oxygen diffusion, tissue ablation using heating, etc. will be used to demonstrate fundamental concepts and develop models to better understand the physics behind these processes.

BIOE 4030–Finite Element Analysis for Bioengineers
Track Elective, 3 credit hours.
This course provides an introduction to finite element analysis (FEA) for bioengineers, including development of CAD tools, image-to-model methods, and simple finite element analysis of mechanics, heat transfer and fluid dynamics applied to biomedical problems.

BIOE 4035–Biomaterials II – Design of Biomaterials
Track Elective, 3 credit hours. This course extends work begun in Biomaterials I by introducing students to the design of novel biomaterials including novel polymer systems, tissue-engineered systems, and artificial/biological composite systems.

9. Additional Proposed Track Electives

BIOE 4420/5420-Polymer Biomaterials
Track Elective, 3 credit hours.
This course will cover fundamental synthetic method and basic characteristics of various polymeric biomaterials and their crucial roles in different biomedical applications. It will cover how the polymers can be modified to enhance biomedical applications. Prerequisite: Graduate standing in Bioengineering or permission of instructor.

**BIOE 4073/5073-Neural interfaces and Biomechanics**  
*Track Elective, 3 credit hours.*  
This course will explore advanced topics in neural interfaces (Brain machine interfaces, peripheral nerve interfaces etc), the issues involved in the design of mechatronic limb systems and the decoding algorithms used to map the neural interface to the mechatronic limb. Restrictions: Matriculated CEAS students.

**BIOE 4046/5046-Advanced Matlab for Lifescientists and Engineers**  
*Track Elective, 3 credit hours.*  
This course covers MatLab programming for bioengineers and life scientists. Topics include MatLab syntax and optimization as well as techniques for working with scalars, time-series, images, and multi-dimension datasets. Surface/Curve fitting, modeling, automation, and classification will be covered as well.

**BIOE 4065/5065-Biofluid Dynamics**  
*Track Elective, 3 credit hours.*

**BIOE 4080/5080-Lasers in Medicine**  
*Track Elective, 3 credit hours.*

**BIOE 4090/5090-Biomedical Imaging II**  
*Track Elective, 3 credit hours.*

**BIOE 4092/5092-Biomedical Optics (with Lab)**  
*Track Elective, 3 credit hours.*

**BIOE 4095/5095-Acquisition and Analysis of Physiological Signals**  
*Track Elective, 3 credit hours.*

**BIOE 4xxx–Introduction to Advanced Engineering Mathematics I**  
*Track Elective, 3 credit hours.*  
This course will deal with analytical techniques applied to engineering problems in transport phenomena, process dynamics and control, and thermodynamics. In this course, the student will learn to model and solve Bioengineering problems with ordinary differential equation and those problems that deal with systems of differential equations. The applications of partial differential equations, Laplace equation and diffusion equation to bioengineering problems are presented.

**BIOE 4xxx–Tissue Engineering**  
*Track Elective, 3 credit hours.*  
In this course, the student will be introduced to a biochemical, biophysical, and molecular view of cell biology. Topics include: biochemistry and biophysical properties of cells, the extracellular matrix, biological signal transduction, and principles of engineering new tissues. Here the student will apply engineering principles to analyze and predict specific cell physiological behaviors, quantitatively analyze
the function and structure of tissues and to rationally design effective strategies for engineered tissues based on these analyses. The student will also understand and apply the designs of biomaterial scaffolds (biomimetic structures) based on naturally derived materials or biodegradable synthetic polymers.

**BIOE 3xxx–Cell and Molecular Engineering**

*Track Elective, 3 credit hours.*

The course will study the fundamentals of genetics and cell biology, engineering of genetic pathways to achieve designated functionalities, bioethics of genetics, genetic engineering, stem cells and cloning, medical and economic ramifications of biotechnology, introduction to genomics, tissue engineering, and stem cell technology, and ability to solve quantitative problems related to genetics and cell biology.

**BIOE 3xxx–Introduction to Thermodynamics of Bimolecular Systems**

*Track Elective, 3 credit hours.*

This subject deals primarily with equilibrium properties of macroscopic and microscopic systems, basic thermodynamics, chemical equilibrium of reactions in gas and solution phase, and macromolecular interactions. This course provides an introduction to the physical chemistry of biological systems. Topics include: connection of macroscopic thermodynamic properties to microscopic molecular properties using statistical mechanics, chemical potentials, equilibrium states, binding cooperatively, behavior of macromolecules in solution and at interfaces, and solvation. Example problems include protein structure, genomic analysis, single molecule biomechanics, and biomaterials. This course also provides a foundation in the thermodynamic principles used to describe biomolecular behavior and interactions such as those that lead to assembly of cell membranes, binding of growth factors to cells, annealing of DNA sequences to oligonucleotides on microarray chips, and separation of complex mixtures of biomolecules for atomic analysis. Many of these problems, as well as related problems in nanotechnology and polymer science, are illuminated by a statistical thermodynamics approach.

**BIOE 3xxx–Physical Chemistry of Biological Systems**

*Track Elective, 3 credit hours.*

This course and laboratory provides an introduction to thermodynamics and its application. We will apply physical chemical concepts to examples from biochemical and biological systems to further our understanding of both physical chemistry and biochemistry.
### 10. AP and IB Assessment

#### A. Pre-Bioengineering AP Credit

<table>
<thead>
<tr>
<th>Subject Area</th>
<th>Examination Title</th>
<th>Minimum Score:</th>
<th>Credit Hours Awarded</th>
<th>UCD Equivalent Course</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biology</td>
<td>Biology - Exam only (See Note 2)</td>
<td>5,4</td>
<td>6</td>
<td>BIOL 2051, BIOL 2061</td>
</tr>
<tr>
<td></td>
<td>Biology Exam and full-year AP course (See Note 3)</td>
<td>5,4,3 (See Note 1)</td>
<td>8</td>
<td>BIOL 2051, BIOL 2062, BIOL 2071, BIOL 2081</td>
</tr>
<tr>
<td>Chemistry</td>
<td>Chemistry - Exam only (See Note 2)</td>
<td>5,4</td>
<td>6</td>
<td>CHEM 2031, CHEM 2061</td>
</tr>
<tr>
<td></td>
<td>Chemistry Exam and full-year AP course (See Note 3)</td>
<td>5,4,3 (See Note 1)</td>
<td>9</td>
<td>CHEM 2031, CHEM 2062, CHEM 2061, CHEM 2068</td>
</tr>
<tr>
<td>Math- Calculus</td>
<td>Calculus AB</td>
<td>5, 4, 3 (See Note 1)</td>
<td>4</td>
<td>MATH 1401</td>
</tr>
<tr>
<td></td>
<td>Calculus (EN) AB</td>
<td>5, 4, 3 (See Note 1)</td>
<td>4</td>
<td>MATH 1401</td>
</tr>
<tr>
<td></td>
<td>Calculus BC</td>
<td>5, 4, 3 (See Note 1)</td>
<td>8</td>
<td>MATH 1401, MATH 2411</td>
</tr>
<tr>
<td></td>
<td>Calculus (EN) BC</td>
<td>5, 4, 3 (See Note 1)</td>
<td>8</td>
<td>MATH 1401, MATH 2411</td>
</tr>
<tr>
<td>Physics</td>
<td>Physics C - Exam Only (Mechanics) (See Note 2)</td>
<td>5,4</td>
<td>4</td>
<td>PHYS 2311</td>
</tr>
<tr>
<td></td>
<td>Physics C - Exam Only (Elec/Mag) (See Note 2)</td>
<td>5,4</td>
<td>4</td>
<td>PHYS 2331</td>
</tr>
<tr>
<td></td>
<td>Physics C (Mechanics) See Note 3</td>
<td>5,4,3 (See Note 1)</td>
<td>4</td>
<td>PHYS 2331, PHYS 2321</td>
</tr>
<tr>
<td></td>
<td>Physics C (Elec/Mag) (See Note 3)</td>
<td>5,4,3 (See Note 1)</td>
<td>4</td>
<td>PHYS 2331, PHYS 2341</td>
</tr>
</tbody>
</table>

**NOTE 1:** An AP exam score of 3 requires a minimum grade of “A” in the second semester of the high school AP course for credit to be awarded.

**NOTE 2:** Students may take the corresponding UC Denver laboratory course to meet a lab science core curriculum or major requirement. See your advisor for additional information.

**NOTE 3:** Students must meet the Bioengineering Major proficiency standards before enrolling in additional laboratory courses. See your advisor for additional information.

#### B. Pre-Bioengineering IB Assessment

<table>
<thead>
<tr>
<th>IB Examinations (Other IB exams may be considered with a minimum score of 4)</th>
<th>Minimum Exam Score</th>
<th>Standard Exam</th>
<th>Higher Exam</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>UCD Equivalent Course</td>
<td>Credit Hours Awarded</td>
<td>UCD Equivalent Course</td>
</tr>
<tr>
<td>Biology</td>
<td>4</td>
<td>BIOL 2051/2071</td>
<td>4</td>
</tr>
<tr>
<td>Chemistry</td>
<td>4</td>
<td>CHEM 2031/2038</td>
<td>4</td>
</tr>
<tr>
<td>Design Technology</td>
<td>4</td>
<td>Not Acceptable (See Note 3)</td>
<td></td>
</tr>
<tr>
<td>Mathematics</td>
<td>4</td>
<td>MATH 1401</td>
<td>3</td>
</tr>
<tr>
<td>Physics</td>
<td>4</td>
<td>PHYS 2010/2030</td>
<td>5</td>
</tr>
</tbody>
</table>

Bioengineering
11. TRANSFER STUDENTS:
With the inaugural class beginning Fall 2013 the only bioengineering courses that will be offered Fall 2013 will be the year 1 courses. The full curriculum will not be available until Fall 2015, therefore, the earliest graduation date for a BS Bioengineering degree is May 2017.

Pre-Bioengineering Transfer Admission Requirements
- One full year of college calculus
- One semester of calculus based physics
- One year general biology and labs
- One year general chemistry and labs

All prerequisite courses must be completed with a grade of B or better. Your cumulative GPA must be at least 2.75. Interested transfer students should contact our advising office at bioengineering@ucdenver.edu or 303-724-7296.

12. Overlap with Pre-Medical Education
Bioengineering is a highly popular option for students interested in medical school. Indeed, a significant percentage of medical school applicants choose bioengineering as their undergraduate degree as it combines the biomedical science requirements for medical school with the highly valued and robust training in technology and engineering. At UC Denver, bioengineering students interested in medical school take all but Organic Chemistry II in the Pre-Bioengineering Core which satisfies the pre-med requirements for most medical schools. Additionally, the UC Denver Bioengineering program provides opportunities for undergraduate research experiences at the Anschutz Medical Campus, providing students with the opportunity to work with practicing clinical researchers and gain valuable pre-clinical experience.