DEPARTMENT OF BIOMEDICAL ENGINEERING (GRAD)

Introduction

The Joint Department of Biomedical Engineering Graduate Program is administered by the combined biomedical engineering graduate faculty from both North Carolina State University and University of North Carolina at Chapel Hill. The joint program also has close working relations with the Research Triangle Institute and industry within the Research Triangle area. These associations enable students to obtain research training in a wide variety of fields and facilitate the selection and performance of dissertation research. Thus, the department, provides students with excellent opportunities to realize the goal of enhancing medical care through the application of modern technology.

Biomedical engineering is a dynamic field stressing the application of engineering techniques and mathematical analysis to biomedical problems. Faculty research programs are key to the program, and they include five primary research directions: rehabilitation engineering, regenerative medicine, biomedical imaging, biomedical microdevices, and pharmacoengineering. The department offers graduate education in biomedical engineering leading to the master of science (M.S.) and doctor of philosophy (Ph.D.) degrees.

Students typically enter this program with backgrounds in engineering, physical science, mathematics, or biological science. Curricula are tailored to fit the needs and develop the potential of individual students. In addition, courses in statistics, mathematics, life sciences, and engineering provide a well-rounded background of knowledge and skills.

Admission Requirements

Students must satisfy all entrance requirements for The Graduate School of the University of North Carolina at Chapel Hill or the Graduate School at North Carolina State University, and must demonstrate interest and capability commensurate with the quality of the biomedical engineering program. Prospective students may apply to the graduate school at either UNC–Chapel Hill or NC State. All applicants are considered together as a group. Generally, applications should be submitted by December 12 for consideration for admission in the coming fall semester. Students are no longer required to submit their GRE scores. Admitted students are expected to have an average grade of B (cumulative GPA 3.30) or better and are encouraged to have undergraduate research experience. The program requires that a one-to-three page personal statement about research interest and background be submitted.

Students should have a good working knowledge of mathematics at least through differential equations, plus two years of physical or engineering science and basic courses in biological science. Deficiencies in preparation can be made up in the first year of graduate training.

Doctoral Degree Requirements

A minimum of 52 semester hours of graduate work is required (beyond the bachelor's degree). Degree candidates in this program are expected to obtain experience working in a research laboratory during their residence and to demonstrate proficiency in research. The Ph.D. dissertation should be judged by the graduate committee to be of publishable quality. The student must meet the Graduate School's residency requirement at UNC-CH or NC State as appropriate. Further information on the BME Ph.D. program can be found on the department website (https://bme.unc.edu/graduate/doctor-of-philosophy/).

Required and Highly Recommended Courses

Students must complete six credits of graduate engineering topics, six credits of graduate life science topics, three credits of engineering mathematics, and three credits of statistics. Nine credits of technical electives are also required. Students may choose from a number of courses to meet these requirements. Such choices are made in consultation with the student's academic advisor and the Director of Graduate Programs/Studies.

Students are required to take a BME Seminar each semester which is offered at both UNC-CH and NC State. Students must also complete a Mentored Teaching Experience and a Professional Development Seminar.

Comprehensive and Qualifying Examinations

Doctoral students qualify for the Ph.D. degree by meeting grade requirements in their core courses, and then advance on to written and oral preliminary exams before admission to candidacy. Details can be found on the department website (https://bme.unc.edu/graduate/doctor-of-philosophy/).

Degrees

- Biomedical Engineering (M.S.): MedTech Innovation and Entrepreneurship Concentration (https://catalog.ncsu.edu/graduate/engineering/biomedical-engineering/biomedical-engineering-ms-translation-innovation-entrepreneurship-concentration/)
- Biomedical Engineering (Ph.D.) (https://catalog.ncsu.edu/graduate/engineering/biomedical-engineering/biomedical-engineering-phd/)
- Biomedical Engineering (Minor) (https://catalog.ncsu.edu/graduate/engineering/biomedical-engineering/biomedical-engineering-minor/)

Department Chair

Paul Dayton

Associate Chairs

Lianne Cartee, Associate Chair for Education
Shawn Gomez, Associate Chair for Research

Directors

Lianne Cartee, Director of Undergraduate Studies
Matthew Fisher, Director of Graduate Studies

Associate Director

Naji Husseini, Associate Director of Undergraduate Studies

Distinguished Professors

Lianne Cartee, Alumni Distinguished Undergraduate Professor
Paul Dayton, William R. Kenan Jr. Distinguished Professor
He (Helen) Huang, Jackson Family Distinguished Professor
H. Troy Nagle
Roger Narayan
Koji Sode, William R. Kenan Jr. Distinguished Professor

Professors

Lianne Cartee
Paul Dayton
Greg M. Forest
Caterina Gallippi
Shawn Gomez
Helen Huang
Leaf Huang
Weili Lin
H. Troy Nagle
Roger Narayan
J. Michael Ramsey
Koji Sode

Associate Professors

Ashley Brown
Yevgeny Brudno
Jacqueline Cole
Michael Daniele
Bob Dennis
Kenneth Donnelly
Oleg Favorov
Matthew Fisher
Jason Franz
Donald Freytes
Michael Gamcsik
David Hill
Devin Hubbard
Naji Husseini
Derek Kamper
David Lalush
Jeffrey Macdonald
Scott Magness
Gianmarco Pinton
Nitin Sharma
Mark Tommerdahl
Anka Veleva
Bruce Wiggin
David Zaharoff

Assistant Professors

Amy Adkins
Pritha Agarwalla
Wen Yih Aw
Rahima Benhabbour
Joseph Burclaff
Melissa Caughey
Silvia Ceballos
Brian Diekman
Alon Greenbaum
Kennita Johnson
Jinwood Kim
Wesley Legant
Ming Liu
Virginie Papadopopoulou
Ross Petrella
William Polacheck
Imran Rizvi
Francisco Santibanez
James Tsuruta

Professors Emeriti

Frank Abrams
Albert Banes
Carol Lucas

Professor of the Practice

Matthew Penny

Lecturers

Sidhartha Jandhyala
Nick Jardine

BMME

Advanced Undergraduate and Graduate-level Courses

BMME 435. Biological Physics. 3 Credits.
How diffusion, entropy, electrostatics, and hydrophobicity generate order and force in biology. Topics include DNA manipulation, intracellular transport, cell division, molecular motors, single molecule biophysics techniques, nerve impulses, neuroscience.

Rules & Requirements
Requisites: Prerequisites, PHYS 116 and 117, or PHYS 118 and 119.
Grading Status: Letter grade.
Same as: PHYS 405, BIOL 431.

BMME 441. Thermal Physics. 3 Credits.
Equilibrium statistical mechanics; the laws of thermodynamics, internal energy, enthalpy, entropy, thermodynamic potentials, Maxwell's relations.

Rules & Requirements
Requisites: Prerequisites, MATH 233, and PHYS 117 or 119; permission of the instructor for students lacking the prerequisites.
Grading Status: Letter grade.
Same as: PHYS 441.

BMME 461. Introduction to Medical Imaging. 3 Credits.
This class covers the underlying concepts and instrumentation of modern medical imaging modalities. Review of applicable linear systems theory and relevant principles of physics. Modalities covered include X-ray radiography (conventional film-screen imaging and modern electronic imaging), computerized tomography (including the theory of reconstruction), magnetic resonance imaging, SPECT/PET, and ultrasound imaging.

Rules & Requirements
Requisites: Prerequisite, BMME 365.
Grading Status: Letter grade.

BMME 486. Biomedical Instrumentation Design and Prototyping II. 2 Credits.
Students will build upon skills learned in BMME 386 and assume project leadership roles as well as team management roles for more complex projects involving design, fabrication, assembly, testing, deployment, and incorporation of user feedback in the design and fabrication of components and systems for research and technology development in biomedical engineering. Students will interact with highly experienced faculty to develop and deploy design solutions for BME laboratories and technology spin-outs.

Rules & Requirements
Requisites: Prerequisite, BMME 386 with a grade of A.
Repeat Rules: May be repeated for credit. 4 total credits. 2 total completions.
Grading Status: Letter grade.

BMME 495. Undergraduate Research in Biomedical Engineering as a Technical Elective. 3 Credits.
Opportunity for hands-on faculty mentored research project in biomedical engineering. Approved plan of work required with significant independent research culminating in a final paper and presentation at an appropriate venue. Departmental approval required. Course may not be repeated. Permission of department.

Rules & Requirements
IDEAs in Action Gen Ed: RESEARCH.
Grading Status: Letter grade.

BMME 505. Skeletal Biomechanics. 3 Credits.
A firm understanding of the principles of mechanics is an important foundation to biomechanics. In this course, students will study the mechanics of materials with applications to the strength of bone, implant analysis, and testing of biological materials. A goal of this course is for students to understand how the interface of biology, mechanics, and therapies affect skeletal pathological conditions.

Rules & Requirements
Requisites: Prerequisites, BMME 160 and MATH 383.
Grading Status: Letter grade.

BMME 511. Genetic Engineering. 3 Credits.
The course introduces the engineering principles used to modify cells in a variety of biomedical applications. The format includes lectures, discussion of primary research literature, and application of engineering design principles through student projects. The goals are to 1) discuss genome editing technologies, 2) evaluate strategies for cellular reprogramming and directed differentiation of stem cells, and 3) illustrate how genetic modification can be harnessed for cellular therapy and research applications such as animal models.

Rules & Requirements
Requisites: Prerequisites, BMME 301 or BMME 302; and BMME 315 or BMME 325; recommended BMME 420 or BIOL 202.
Grading Status: Letter grade.

BMME 521. Introduction to Synthetic Biology. 3 Credits.
This course provides an introduction to the ideas and methodologies in the field of synthetic biology. Lectures focus on fundamental concepts in molecular biology and engineering as applied to biological system design. The laboratory portion of the course provides hands-on application of fundamental techniques in synthetic biology research. Previously offered as BMME 420. Majors only.

Rules & Requirements
Requisites: Pre- or corequisites, BMME 325 or CHEM 430; and BMME 335.
Grading Status: Letter grade.

BMME 523. Biomolecular Engineering. 3 Credits.
This course introduces the use and creation of biomolecules for biomedical applications to foster the development of a mission oriented research plan to create engineered biomolecules for biomedical applications. Students will search, prepare, evaluate, design, and simulate biomolecules through lectures on the basic chemical and structural properties of biomolecules, exploiting varieties of biomolecules, practical methods to engineer biomolecules, and development of a student research plan. BME students only.

Rules & Requirements
Requisites: Prerequisite, BMME 325 or CHEM 430.
Grading Status: Letter grade.

BMME 524. Biomolecular Sensing Technologies. 3 Credits.
This course introduces the science and technology of biomolecular sensing technologies, the essence of biosensors, and biochemical and immunological in vitro/in vivo diagnostic devices. The focus of the class is biomolecules (enzymes, antibodies, binding proteins, receptors, aptamers, molecularly imprinted polymers, etc.), bioelectronics and biochemical principles employed in biosensor development. Majors only.

Rules & Requirements
Requisites: Prerequisite, BMME 325 or CHEM 430; recommended BMME 420 or BMME 511.
Grading Status: Letter grade.

BMME 527. Targeted Photomedicine. 3 Credits.
This course will introduce students to fundamental concepts and engineering approaches in targeted photomedicine, particularly for the treatment of cancer. Students will review and present research articles on emerging applications of photomedicine. The major deliverable will be an NIH-style research proposal, based on lecture material and a literature review, to help students gain an understanding of advancements in targeted photomedicine.

Rules & Requirements
Requisites: Prerequisites, BMME 325 or CHEM 430; and BMME 301 or 302.
Grading Status: Letter grade.

BMME 543. Biomechanics of Movement. 3 Credits.
This course provides an overview of musculoskeletal anatomy, and of the mechanical behavior of biological tissues and biological systems. Students learn to apply fundamental principles of mechanics to analyze movement in humans and other animals. Applications in rehabilitation and orthopedics are emphasized. Previously offered as BMME 405 and BMME 503.

Rules & Requirements
Requisites: Prerequisites, BMME 160, or 205, and MATH 383.
Grading Status: Letter grade.

BMME 545. Systems Neuroscience. 3 Credits.
Introduction to methodologies used to characterize a) the aggregate behavior of living neural networks and b) the changes in that behavior that occur as a function of stimulus properties, pharmacological manipulations, and other factors that dynamically modify the functional status of the network. Previously offered as BMME 445.

Rules & Requirements
Requisites: Prerequisite, BMME 351 or BMME 301 or BIOL 252.
Grading Status: Letter grade.

BMME 547. Neural Basis of Rehabilitation Engineering. 3 Credits.
The course will 1) introduce basic neuroscience topics underlying sensorimotor control, and 2) introduce different types of childhood and adult neuromuscular disorders with both central and peripheral origins. The main focus of the class will be on the different techniques used for diagnosis, assessment, and rehabilitation interventions. Previously offered at BMME 447.

Rules & Requirements
Requisites: Prerequisites, BMME 301 and BMME 345.
Grading Status: Letter grade.

BMME 550. Medical Imaging I: Ultrasonic, Optical, and Magnetic Resonance Systems. 3 Credits.
Physical and mathematical foundations of ultrasonic, optical, and magnetic resonance imaging systems in application to medical diagnostics. Each imaging modality is examined, highlighting critical system characteristics: underlying physics of the imaging system, including mechanisms of data generation and acquisition; image creation; and relevant image processing methods, such as noise reduction.

Rules & Requirements
Requisites: Prerequisites, BIOS 550 and PHYS 128.
Grading Status: Letter grade.

BMME 551. Medical Device Design I. 3 Credits.
Student multidisciplinary teams work with local medical professionals to define specific medical device concepts for implementation.

Rules & Requirements
Grading Status: Letter grade.

BMME 552. Medical Device Design II. 3 Credits.
Device prototypes designed in the first course in series. Good manufacturing practices; process validation; FDA quality system regulations; design verification and validation; regulatory approval planning; and intellectual property protection.

Rules & Requirements
Grading Status: Letter grade.

BMME 555. Biofluid Mechanics. 3 Credits.
This course introduces students to basics of fluid mechanics (steady and pulsatile flows, laminar and turbulent flows, and Newtonian and non-Newtonian flows). Students learn the fundamental relationships and governing equations describing these types of flows and the basic physiology of certain systems that are highly associated with fluid flows. Previously offered as BMME 455.

Rules & Requirements
Requisites: Prerequisites, BMME 315 and one of BMME 205 or BMME 160.
Grading Status: Letter grade.

BMME 560. Medical Imaging II: X-Ray, CT, and Nuclear Medicine Systems. 3 Credits.
Overview of medical imaging systems using ionizing radiation. Interaction of radiation with matter. Radiation production and detection. Radiography systems and applications. Tomography. PET and SPECT systems and applications.

Rules & Requirements
Requisites: Prerequisites, BIOS 550, BMME 410, and PHYS 128.
Grading Status: Letter grade.

BMME 565. Biomedical Instrumentation I. 4 Credits.
Graduate students or permission of the instructor. Topics include basic electronic circuit design, analysis of medical instrumentation circuits, physiologic transducers (pressure, flow, bioelectric, temperate, and displacement). This course includes a laboratory where the student builds biomedical devices.

Rules & Requirements
Grading Status: Letter grade.

BMME 568. Super Resolution-Imaging Beyond Limits. 3 Credits.
All imaging systems have limitations due to hardware specifications or fundamental physical principles. This course will focus on ways to surpass these limits through experimental design, new physical principles, and deep learning/computational processing. Toward this end, we will cover the fundamental mechanisms of image formation in the most common biomedical imaging modalities and describe recent approaches to extend resolution beyond conventional limits.

Rules & Requirements
Requisites: Prerequisites, BMME 365 and [COMP 116 or BMME 201] or by permission from instructor.
Grading Status: Letter grade.

BMME 572. Analysis of Tissue Engineering Technologies. 3 Credits.
Lectures in this course address how to quantitatively evaluate functional engineered tissues. The course provides an overview of the field, with emphasis on detailed evaluation of scientific and commercial progress over time, and design principles that must be met to develop a process or fabricate a functional tissue-engineered part. Previously offered as BMME 470 and BMME 570.

Rules & Requirements
Requisites: Prerequisites, BMME 335 or BMME 351, and BMME 302 or BIOL 252.
Grading Status: Letter grade.

BMME 575. Practical Machine Learning for Biosignal Analysis. 3 Credits.
This graduate level course will introduce practical machine learning concepts and tools, and will exemplify their application to the analysis of biological signals and images, including brain imaging, electrophysiology, and image recognition. MATH 347 recommended.

Rules & Requirements
Requisites: Prerequisites, COMP 116 and MATH 233; permission of instructor for students lacking the prerequisites.
Grading Status: Letter grade.

BMME 576. Mathematics for Image Computing. 3 Credits.
Mathematics relevant to image processing and analysis using real image computing objectives and provided by computer implementations.

Rules & Requirements
Requisites: Prerequisites, COMP 116 or 210 or 401, and MATH 233; a grade of C or better is required in all prerequisites.
Grading Status: Letter grade.
Same as: COMP 576.

BMME 581. Microcontroller Applications II. 3 Credits.
Advanced topics in microcontroller systems used for biomedical instruments. Problems of interfacing computers with biomedical systems are studied. Students collaborate to develop a new biomedical instrument. Platforms could include the use of digital signal processing (DSP) microcontrollers or field programmable gate arrays (FPGAs), and topics could include applications such as digital signal processing and high speed data acquisition to computers.

Rules & Requirements
Requisites: Prerequisites, BMME 375 and 385 or equivalent.
Grading Status: Letter grade.

BMME 585. Biotechnology. 3 Credits.
This course is designed to prepare a biomedical engineering student with the survey tools to understand key components in modern biotechnologies. Fundamental concepts, theory, design, operation, and analysis of the most common biotechnologies in bioengineering will be presented. Previously offered as BMME 485.

Rules & Requirements
Requisites: Prerequisite, BMME 325.
Grading Status: Letter grade.

BMME 590. Special Topics in Biomedical Engineering. 1-9 Credits.
A study in the special fields under the direction of the faculty. Offered as needed for presenting material not normally available in regular BMME courses. Previously offered as BMME 490. Majors only.

Rules & Requirements
Repeat Rules: May be repeated for credit; may be repeated in the same term for different topics; 12 total credits. 12 total completions.
Grading Status: Letter grade.

BMME 681. Human Factors Engineering and Quality Management Systems for Engineers. 3 Credits.
This course teaches human factors engineering, risk assessment, and quality management systems. At the end of the course, students will be able to apply their knowledge to their senior design project and test for a six sigma green belt certification.

Rules & Requirements
Grading Status: Letter grade.

BMME 691H. Honors Thesis. 3 Credits.
Research honors course. Prior approval needed from the chair or associate chair of the program for topic selection and faculty research mentor. Minimum GPA requirement, written report, and abstract requirements as set forth by the honors program.

Rules & Requirements
IDEAs in Action Gen Ed: RESEARCH.
Making Connections Gen Ed: EE- Mentored Research.
Grading Status: Letter grade.

BMME 692H. Honors Thesis. 3 Credits.
Research honors thesis continuation with required GPA, research topic selection with approved faculty mentor. Written abstract and report per honors program guidelines submitted by specific deadlines.

Rules & Requirements
IDEAs in Action Gen Ed: RESEARCH.
Making Connections Gen Ed: EE- Mentored Research.
Grading Status: Letter grade.

BMME 697. BME Senior Design: Product Development. 3 Credits.
This course is part of a three year sequence and it expands on the skills and knowledge gained in BM(M)E 398. Students continue to learn the process of engineering design and learn new skills to produce solutions for unmet medical needs. Majors only.

Rules & Requirements
IDEAs in Action Gen Ed: FC-CREATE, COMMBEYOND.
Requisites: Prerequisites, BMME 398 and BMME 301 or 302; and two specialization or gateway electives.
Grading Status: Letter grade.

BMME 698. Biomedical Engineering Senior Design: Product Implementation and Strategy. 3 Credits.
This course is part of a three-year sequence and it expands on the skills and knowledge gained in prior design courses. Students continue to learn the process of engineering design and learn new skills to produce solutions for unmet medical needs. Implementation phase of the senior design experience.

Rules & Requirements
IDEAs in Action Gen Ed: RESEARCH.
Making Connections Gen Ed: CI, EE- Mentored Research.
Requisites: Prerequisites, BMME 398 and BMME 301 or 302; 2 gateway or specialization electives; Pre- or corequisite, 3 additional gateway or specialization electives.
Grading Status: Letter grade.

Graduate-level Courses

BMME 740. Advanced Biomaterials. 3 Credits.
Medical or dental implants or explants are highlighted from textbooks, scientific literature, and personal accounts.

Rules & Requirements
Requisites: Prerequisite, BMME 510; Permission of the instructor for students lacking the prerequisite.
Grading Status: Letter grade.
Same as: MTSC 740.

BMME 770. Physiology and Methods in Genomics. 4 Credits.
Lectures in physiology systems and lab techniques covering various functional genomic methods including DNA sequencing, gene arrays, proteomics, confocal microscopy, and imaging modalities.

Rules & Requirements
Grading Status: Letter grade.

BMME 775. Image Processing and Analysis. 3 Credits.
Approaches to analysis of digital images. Scale geometry, statistical pattern recognition, optimization. Segmentation, registration, shape analysis. Applications, software tools.

Rules & Requirements
Requisites: Prerequisites, MATH 233, MATH 547/347, and STOR 435.
Grading Status: Letter grade.
Same as: COMP 775.

BMME 780. Advanced Materials Science. 3 Credits.
This course covers the physical fundamentals of material science with an in-depth discussion of structure formation in soft and hard materials and how structure determines material mechanical, electrical, thermal, and optical properties. Topics include amorphous and crystal structures, defects, dislocation theory, thermodynamics and phase diagrams, diffusion, interfaces and microstructures, solidification, and theory of phase transformation. Special emphasis will be on the structure-property relationships of (bio)polymers, (nano)composites, and their structure property relationships.

Rules & Requirements
Grading Status: Letter grade.
Same as: MTSC 780, CHEM 780, PHYS 780.

BMME 790. Graduate Systems Physiology. 3 Credits.
This is the second semester of the two-semester series intended to provide graduate students with an introduction to systems and organ physiology.

Rules & Requirements
Requisites: Prerequisite, BMME 589.
Grading Status: Letter grade.

BMME 795. Information Processing in the Central Nervous System. 3 Credits.
Introduction to methodologies used to characterize a) the aggregate behavior of living neural networks and b) the changes in that behavior that occurs as a function of stimulus properties, pharmacological manipulations, and other factors that dynamically modify the functional status of the network.

Rules & Requirements
Requisites: Prerequisite, BMME 589.
Grading Status: Letter grade.

BMME 796. Seminar in Biomedical Imaging Science. 3 Credits.
This course serves as a gateway course to the Graduate Certificate in Biomedical Imaging Science. This course offers an introduction to the most common imaging modalities, including MR, CT, PET, SPECT, ultrasound, and optical imaging. Lectures include discussions of hardware, physics, as well as pre-clinical and clinical applications.

Rules & Requirements
Grading Status: Letter grade.
Same as: PSYC 796.

BMME 810. Digital Nuclear Imaging. 3 Credits.
Advanced topics of physics and instrumentation in nuclear imaging and magnetic resonance techniques.

Rules & Requirements
Requisites: Prerequisites, BMME 550 and 560.
Grading Status: Letter grade.

BMME 840. Rehabilitation Engineering Design. 4 Credits.
Students will design an assistive technology device to help individuals with disabilities to become more independent. The project will be used in the community when it is completed.

Rules & Requirements
Requisites: Prerequisite, BMME 465; Permission of the instructor for students lacking the prerequisite.
Grading Status: Letter grade.

BMME 890. Special Topics. 1-21 Credits.
Permission of the instructor. Special library and/or laboratory work on an individual basis on specific problems in biomedical engineering and biomedical mathematics. Direction of students is on a tutorial basis and subject matter is selected on the basis of individual needs and interests.

Rules & Requirements
Repeat Rules: May be repeated for credit; may be repeated in the same term for different topics.
Grading Status: Letter grade.

BMME 900. Research in Biomedical Engineering and Biomathematics. 1-21 Credits.
Permission of the instructor.

Rules & Requirements
Grading Status: Letter grade.

BMME 993. Master's Research and Thesis. 3 Credits.
Rules & Requirements
Repeat Rules: May be repeated for credit.

BMME 994. Doctoral Research and Dissertation. 3 Credits.
Rules & Requirements
Repeat Rules: May be repeated for credit.

Contact Information

Department of Biomedical Engineering
Visit Program Website (http://www.bme.unc.edu)

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