

# DEPARTMENT OF BIOMEDICAL ENGINEERING (GRAD)

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, biomedical imaging, pharmacoengineering, regenerative medicine, and biomedical microdevices. The department offers graduate education in biomedical engineering leading to the master of science and doctor of philosophy degrees. Also, a joint graduate certificate in medical devices is offered.

Students 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 sciences provide a well-rounded background of knowledge and skills.

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

## 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 North Carolina State University. All applicants are considered together as a group. Generally, applications should be submitted by mid-December for consideration for admission in the coming fall semester. Applicants are expected to present Graduate Record Examination (GRE) scores; verbal scores should be at or above the 50th percentile, and quantitative scores should be at or above the 70th percentile. Applicants are expected to have at least a 30th percentile score on the written GRE component to be competitive. The program requires applicants to submit a one- to three-page personal statement about their research interest and background.

Students should have a good working knowledge of mathematics at least through differential equations, as well as 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.

Candidates for the UNC–Chapel Hill/North Carolina State University jointly issued degrees in biomedical engineering must have met the general requirements of The Graduate School of the University of North Carolina at Chapel Hill or the North Carolina State University Graduate School.

\*Currently matriculating\* master's students are required to take a comprehensive examination encompassing coursework and thesis research. The master's comprehensive exam may be either written or oral and is administered by the student's advisory committee.

Doctoral students qualify for the Ph.D. degree by meeting grade requirements in their core courses and then advancing to written and oral preliminary exams before admission to candidacy. Details can be found on the department's website (<https://bme.unc.edu/>). 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.

## Professors

Lianne Cartee, Ke Cheng, Paul Dayton, M. Gregory Forest, Caterina Gallippi, Shawn Gomez, Edward Grant, Helen Huang, Leaf Huang, Michael Jay, Weili Lin, H. Troy Nagle, Roger Narayan, J. Michael Ramsey, Koji Sode.

## Associate Professors

Ted Bateman, Ashley Brown, Jacqueline Cole, Michael Daniele, Bob Dennis, Kenneth Donnelly, Oleg Favorov, Matthew Fisher, Jason Franz, Donald Freytes, Michael Gamcsik, Devin Hubbard, Naji Hussein, 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, Rahima Benhabbour, Yevgeny Brudno, Melissa Caughey, Silvia Ceballos, Brian Diekman, Marc Foster, Andrea Giovannuci, Alon Greenbaum, Kennita Johnson, Jinwood Kim, Wesley Legant, Ming Liu, Virginie Papadopoulos, Ross Petrella, William Polacheck, Imran Rizvi, Francisco Santibanez, Michael Sano, James Tsuruta.

## Professors Emeriti

Frank Abrams, Albert Banes, Carol Lucas.

## Professor of the Practice

Matthew Penny.

## BMME

### Advanced Undergraduate and Graduate-level Courses

#### **BMME 405. 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.

#### **Rules & Requirements**

**Requisites:** Prerequisites, BMME 160, or 205, and MATH 383.

**Grading Status:** Letter grade.

**BMME 420. 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. Majors only.

**Rules & Requirements**

**Requisites:** Pre- or corequisites, BMME 325 or CHEM 430; and BMME 335.

**Grading Status:** Letter grade.

**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 445. 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.

**Rules & Requirements**

**Requisites:** Prerequisite, BMME 351 or BMME 301 or BIOL 252.

**Grading Status:** Letter grade.

**BMME 447. 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.

**Rules & Requirements**

**Requisites:** Prerequisites, BMME 301 and BMME 345.

**Grading Status:** Letter grade.

**BMME 455. 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.

**Rules & Requirements**

**Requisites:** Prerequisites, BMME 315 and one of BMME 205 or BMME 160.

**Grading Status:** Letter grade.

**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 470. 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.

**Rules & Requirements**

**Requisites:** Prerequisites, BMME 335 or BMME 351, and BMME 302 or BIOL 252.

**Grading Status:** Letter grade.

**BMME 485. 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.

**Rules & Requirements**

**Requisites:** Prerequisite, BMME 325.

**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 490. 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. 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 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 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 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 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 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 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 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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