Tulane University reserves the right to change any of its rules, courses, regulations and charges without notice and to make such changes applicable to students already registered as well as to new students. Although we make every effort to verify the accuracy of the information in this booklet, errors may still be present.
Dear Prospective or Current Student:

This booklet includes detailed descriptions of our department - the faculty, our research, the courses we teach, and the requirements for the degrees we offer.

The term “Biomedical Engineering” covers the application of engineering techniques and principles to problems and processes in biology or medicine. Our department was founded in 1977, so we are a relatively mature department in a new field - a field where the potential for making meaningful contributions is unlimited. Our backgrounds are diverse, covering the areas of biomechanics, biomaterials, bioelectronics, bioinformatics and tissue engineering. All of the faculty are actively engaged in research sponsored by federal, state and/or private organizations, and we believe that this enhances our teaching abilities by keeping us at the forefront of knowledge in our specialties. You will find that Tulane's Department of Biomedical Engineering is internationally recognized for our research and for the quality of our teaching and mentorship. Each of the faculty members is committed to helping you acquire the very best education.

At the undergraduate level, the emphasis chosen by our faculty is, first and foremost, to provide students with the opportunity to acquire a rigorous engineering education with an emphasis on scientific principles and interdisciplinary investigation. This foundation serves as a springboard to the study of biomaterials and tissue engineering, bioelectronics, biomechanics and design that will prepare our students for graduate school, medical school, or a position in industry.

At the graduate level we consider our students to be junior colleagues, and we furnish them with the advanced coursework, professional guidance, and equipment/facilities that are critical to their development as independent scholars. We have the resources, experience and energy that are required to mentor our students as they conduct independent research and pursue careers related to one of the major themes of biomedical engineering.

While written material and the information on our web site http://tulane.edu/sse/bme/ may be effective in answering general questions about study in biomedical engineering at Tulane, it cannot convey the enthusiasm that we feel for the work we are doing. If you are a prospective student, please feel free to write or e-mail; however, frequently a personal visit is the most effective way for you to decide whether you wish to join us. We will be happy to show you our facilities, introduce you to the faculty, and discuss the field of biomedical engineering with you if you make an appointment to visit us here in New Orleans.

I appreciate your interest in Tulane’s Department of Biomedical Engineering and hope you will decide to join us.

Sincerely,

[Signature]

Donald P. Gaver, Ph. D.
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1.a. Departmental Mission Statement
Our mission is to inspire and work with students as we develop and apply engineering methods to confront health science challenges.

1.b. Departmental Vision
The Department of Biomedical Engineering is committed to being a global leader in biomedical engineering scholarship. Our faculty, staff, and students are all important parts of the team that provide distinctive opportunities for creative interdisciplinary solutions to biomedical engineering research and design problems. We aim for: excellence in undergraduate and graduate education; meaningful and innovative research; and service dedicated to advancing the field of Biomedical Engineering.

1.c. The Community
Tulane University is located in Uptown New Orleans, a beautiful residential section in one of America’s most distinctive cities. The area offers many cultural and recreational opportunities. Plays, concerts, and movies on campus are numerous. The city has long been known as the birthplace of jazz, and continues to be a major force in musical innovation and performance. Sailing, boating, and fishing are popular on Lake Pontchartrain (15 minutes from campus) and the beaches of the Mississippi Gulf Coast are less than an hour’s drive from New Orleans. The sports enthusiast can watch the Tulane Green Wave in the new Yulman Stadium and the New Orleans Saints play in the Mercedes-Benz Superdome, attend basketball and baseball games on campus, and Babycakes (minor league baseball), and New Orleans Pelicans (NBA basketball) games off campus.
There are many opportunities to participate in intramural sports, or to use the sports facilities of the Reily Center. Mardi Gras and its preliminary festivities offer pageantry unparalleled in the United States. The picturesque plantations and bayou country surrounding New Orleans provide many opportunities for pleasant weekend trips.

Cajun and Creole food from Louisiana is world-renowned.

1.d. The University and the Department
Tulane is a private, nonsectarian university offering a wide range of undergraduate, professional, and graduate courses of study for men and women. Students are selected without regard to race, sex or religion. Tulane enrolls approximately 8,400 undergraduate and 5,000 graduate and professional students each year. About a third of the undergraduate student body is in the School of Science and Engineering.

Tulane’s Biomedical Engineering (BMEN) Department evolved from joint research efforts among faculty in the School of Science and Engineering and the Schools of Medicine at Tulane and the Louisiana State University Medical Center in New Orleans. Undergraduate BMEN degrees were first awarded in 1974, and in 1977 four tenured members of the Mechanical Engineering faculty, plus one new hire, formed the separate BMEN Department. In the past 40 years research in Tulane’s Department of Biomedical Engineering has matured from having a mechanics-oriented focus to a broader range of investigations that encompasses biotransport, biomechanics (fluid and solid), biomaterials and cell-tissue engineering. We have developed a strong expertise in computational modeling and analysis with specific foci on investigations of ocular biomechanics, microvascular research, pulmonary mechanics and biomaterials investigations of the neural system. The undergraduate program has been ABET accredited continuously since 1981, and is one of the largest majors in the School of Science and Engineering with approximately 235 undergraduates and 40 graduate students.

The Biomedical Engineering program represents one of Tulane's areas of excellence, achieving national recognition in many periodic surveys.
2.a. Undergraduate Program Objectives
Our undergraduate program provides students with the breadth required for participation in the interdisciplinary field of biomedical engineering and the depth required by engineers to advance the practice in our discipline. Our objective is to prepare graduates who are able to successfully pursue:
• advanced studies leading to research or professional practice in biomedical engineering
• advanced studies leading to research or professional practice in the health and medical sciences
• practice in biomedical engineering industries or related technical and professional fields.

2.b.1. Undergraduate Instructional Outcomes
By the time of graduation, our students are expected to have these skills, common to all engineers:
• an ability to apply knowledge of mathematics, science, and engineering.
• an ability to design and conduct experiments, as well as to analyze and interpret data.
• 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.
• an ability to function on multi-disciplinary teams.
• an ability to identify, formulate, and solve engineering problems.
• an understanding of professional and ethical responsibility.
• an ability to communicate effectively.
• the broad education necessary to understand the impact of engineering solutions in a global and societal context.
• a recognition of the need for, and an ability to engage in life-long learning.
• a knowledge of contemporary issues.
• an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

2.b.2. Undergraduate Program Criteria
In addition to the Outcomes listed above, we prepare graduates to have an understanding of biology and physiology, and the capability to apply advanced mathematics (including differential equations and statistics), science, and engineering to solve the problems at the interface of engineering and biology. Our curriculum prepares graduates with the ability to make measurements on and interpret data from living systems, addressing the problems associated with the interaction between living and non-living materials and systems.

2.c. Undergraduate Curriculum and Degree Requirements
The undergraduate program in Biomedical Engineering is built upon a rigorous engineering science foundation that is, in turn, based upon a broad curriculum of natural sciences, mathematics, electives in humanities and social sciences, and design. Although students are encouraged to concentrate their professional electives in a sub-field of interest in biomedical engineering (e.g., biomechanics, bioelectronics, bioelectricity, biomaterials, or tissue engineering) or medical sciences (for pre-med students), there are no formal “tracks” within the sequence. The undergraduate curriculum is designed primarily to prepare our undergraduates for advanced study. More than two-thirds of our BSE graduates continue on to graduate or professional training after graduation from Tulane. Our philosophy of ‘rigorous breadth’ in biomedical engineering can best be characterized by the undergraduate curriculum described below. This sample curriculum is applicable to the Class of 2016; exact programs of study for other class years are posted on the department website.
<table>
<thead>
<tr>
<th>Year</th>
<th>Fall Semester 17 Hours</th>
<th>Spring Semester 18 Hours</th>
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</thead>
<tbody>
<tr>
<td><strong>Year 1</strong></td>
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<tr>
<td>Fall Semester 17 Hours</td>
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<tr>
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<tr>
<td>CHEM 1070/1170</td>
<td>General Chemistry I &amp; Lab (4)</td>
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<tr>
<td>ENGL 1010</td>
<td>Writing (4)</td>
<td></td>
</tr>
<tr>
<td>PHYS 1310</td>
<td>General Physics I &amp; Lab (4)</td>
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<tr>
<td>TIDES</td>
<td>Tulane Inter. Exp. Sem. (1)</td>
<td></td>
</tr>
<tr>
<td>*****</td>
<td>*Service Learn (1) (1st or 2nd year)</td>
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<tr>
<td>Spring Semester 18 Hours</td>
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<td></td>
</tr>
<tr>
<td>MATH 1220</td>
<td>Calculus II (4)</td>
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</tr>
<tr>
<td>CHEM 1080/1180</td>
<td>General Chemistry II &amp; Lab (4)</td>
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<tr>
<td>CULT</td>
<td>Cultural Knowledge Elective (3)</td>
<td></td>
</tr>
<tr>
<td>PHYS 1320</td>
<td>General Physics II &amp; Lab (4)</td>
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</tr>
<tr>
<td>ENGP 1410</td>
<td>Statics (3)</td>
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<table>
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<tr>
<td>Fall Semester</td>
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</tr>
<tr>
<td>MATH 2210</td>
<td>Calculus III (4)</td>
<td></td>
</tr>
<tr>
<td>CELL 1010/2115</td>
<td>General Biology I &amp; Lab (4)</td>
<td></td>
</tr>
<tr>
<td>ENGP 2010/2011</td>
<td>Electric Circuits &amp; Lab (4)</td>
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</tr>
<tr>
<td>ENGP 2430</td>
<td>Mechanics of Materials (3)</td>
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<tr>
<td>BMEN 2310</td>
<td>Product &amp; Expt'l Design (3)</td>
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<tr>
<td>Spring Semester</td>
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<tr>
<td>MATH 2240</td>
<td>Applied Math (Diff Eqns.) (4)</td>
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<td>BMEN 2600</td>
<td>Intro Organic &amp; Bio-Chem (3)</td>
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<tr>
<td>BMEN 2730</td>
<td>Biomedical Electronics &amp; Lab (4)</td>
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<tr>
<td>ENGP 3120</td>
<td>Materials Science &amp; Engr (3)</td>
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<tr>
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<tr>
<td>BMEN 3030/3035</td>
<td>Anat &amp; Physiol for Engr &amp; Lab (4)</td>
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</tr>
<tr>
<td>BMEN 3440</td>
<td>Biofluid Mechanics (3)</td>
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<tr>
<td>BMEN 4900</td>
<td>Art of Professional Engr (1)</td>
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<td>BMEN 3xxx</td>
<td>&quot;Domain&quot; class (3)</td>
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<td>CULT</td>
<td>Cultural Knowledge Elective (3)</td>
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<tr>
<td><strong>PELECT</strong></td>
<td>Professional Elective (3)</td>
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<tr>
<td>Spring Semester</td>
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<td></td>
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<tr>
<td>BMEN 3070/3075</td>
<td>Quantitative Physiology &amp; Lab (4)</td>
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<td>BMEN 3820</td>
<td>Math Modeling (3)</td>
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<td>CULT</td>
<td>Cultural Knowledge Elective (3)</td>
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</tr>
<tr>
<td>BMEN 490x</td>
<td>Research &amp; Prof. Practice I (2)</td>
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</tr>
<tr>
<td>BMEN 3xxx</td>
<td>&quot;Domain&quot; class (3)</td>
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<table>
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<tr>
<th>Year 4</th>
<th>14 Hours</th>
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<tbody>
<tr>
<td>Fall Semester</td>
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<tr>
<td>BMEN 4030</td>
<td>Team Design I (2)</td>
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</tr>
<tr>
<td>BMEN 491x</td>
<td>Research &amp; Prof. Practice II (2)</td>
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</tr>
<tr>
<td>BMEN 6710</td>
<td>BMEN Seminar (0)</td>
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<tr>
<td>CULT</td>
<td>Cultural Knowledge Elective (3)</td>
<td></td>
</tr>
<tr>
<td><strong>PELECT</strong></td>
<td>Professional Elective (3)</td>
<td></td>
</tr>
<tr>
<td><strong>PELECT</strong></td>
<td>Professional Elective (3)</td>
<td></td>
</tr>
<tr>
<td>Spring Semester</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BMEN 4040</td>
<td>Team Design II (3)</td>
<td></td>
</tr>
<tr>
<td>BMEN 6720</td>
<td>BMEN Seminar (0)</td>
<td></td>
</tr>
<tr>
<td>CULT</td>
<td>Cultural Knowledge Elective (3)</td>
<td></td>
</tr>
<tr>
<td>CULT</td>
<td>Cultural Knowledge Elective (3)</td>
<td></td>
</tr>
<tr>
<td><strong>PELECT</strong></td>
<td>Professional Elective (3)</td>
<td></td>
</tr>
</tbody>
</table>

129 Credit Hours

§Students with strong preparation will take MATH 1310 or MATH 2210
*Students must take a Service Learning class during their first two years (noted in credits for 1st semester of Year 1).
**Students take 4 Professional Electives. At least one must be a BMEN 6xxx graduate course as a follow-up to a BMEN 3xxx domain course.

Director of Undergraduate Studies – Dr. Lars G. Gilbertson

Class of 2019 Dr. Brown, Dr. Moore
Class of 2020 Dr. Gaver, Dr. Bayer
Class of 2021 Dr. Anderson, Dr. Moore
Class of 2022 Dr. Miller, Dr. Bull
<table>
<thead>
<tr>
<th>Biomedical Design</th>
<th>Biomaterials and Tissue Engineering</th>
<th>Biomechanics and Biotransport</th>
<th>Biosignals and Bioimaging</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMEN3xxx courses</td>
<td>BMEN3xxx courses</td>
<td>BMEN3xxx course</td>
<td>BMEN3xxx courses</td>
</tr>
<tr>
<td>3932 Elements of BMEN Design</td>
<td>3400 Biomaterials &amp; Tissue Engineering</td>
<td>3650 Biomechanics &amp; Transport</td>
<td>3730 Biomedical signals and systems</td>
</tr>
<tr>
<td>BMEN6xxx courses</td>
<td>BMEN6xxx courses</td>
<td>BMEN6xxx courses</td>
<td>BMEN6xxx courses</td>
</tr>
<tr>
<td>6790 Design Studio</td>
<td>6260 Molecular Principles of Functional Biomaterials</td>
<td>6330 Advanced Biofluid Mechanics</td>
<td>6060 Biomedical Acoustics</td>
</tr>
<tr>
<td>6930 TRIZ Theory Invention Design</td>
<td>6430 Vascular Bioengineering</td>
<td>6600 Comp. Modeling of Biomedical Systems</td>
<td>6170 Biomedical Optics</td>
</tr>
<tr>
<td>6080 Tech Invention &amp; Commercialization</td>
<td>6680 Orthopedic Bioengineering</td>
<td>6310 Continuum Models in Biomedical Engineering</td>
<td>6430 Vascular Bioengineering</td>
</tr>
<tr>
<td>SCEN 6000 Entrepreneurship in Eng and Bioscience</td>
<td>6220 Neural Microengineering</td>
<td>6340 Soft Tissue Mechanics</td>
<td>6830 Intro to Biomedical Imaging and Image Processing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6680 Orthopedic Bioengineering</td>
<td>6840 Medical Imaging Physics</td>
</tr>
</tbody>
</table>

Table 1: BMEN 3xxx Domain Courses and the BMEN6xxx Professional Electives which follow them

Research and Design Experiences

Hallmarks of our curriculum are the research and design experiences that are coordinated through the two semester sequences in Research and Professional Practice (4900, plus either 4901/4911 or 4902/4912) and Team Design (4030, 4040). Every student participates in a research project as well as a team design project.

The team design projects, which are supported by the National Science Foundation, are tailored to the needs of clients with disabilities who are referred to the department by several community agencies. The team designs are evaluated for safety and then presented and judged in a public design competition. Each class completes team projects (generally four students per team). A list and brief description is included in the Appendices. The team design experience of working for an extended period with a client with a disability—while having the opportunity to apply engineering foundations and real world design and construction skills to assist the client—has been extremely rewarding for our students.

In addition to the team design project, each student participates in a yearlong research project generally with a biomedical engineering faculty member or with faculty in departments of the Tulane or LSU medical schools. The list of research projects completed by each class covers an impressive range of activities. The students thus have substantial research experience, while still undergraduates that includes writing a comprehensive thesis describing the research performed and an oral presentation of the work to the faculty and fellow students during the annual "Undergraduate Research Day Conference." A list of the recent undergraduate research projects is included in the Appendices.
2.c.1. Tulane Core Requirements

Several of the Tulane-Newcomb College Core Requirements are satisfied during completion of the Biomedical Engineering curriculum.

<table>
<thead>
<tr>
<th>Core Requirement</th>
<th>Satisfied by</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foreign Language</td>
<td>Not required for BSE degree</td>
</tr>
<tr>
<td>Writing (4 credits, first year)</td>
<td>ENGL1010 or equivalent</td>
</tr>
<tr>
<td>Quantitative Reasoning (3-4 credits)</td>
<td>MATH1210 or equivalent</td>
</tr>
<tr>
<td>Science (3-4 credits)</td>
<td>PHYS1310</td>
</tr>
<tr>
<td>Science with Lab (3-4 credits)</td>
<td>CHEM1070/1170</td>
</tr>
<tr>
<td>Cultural Knowledge (12 credits)</td>
<td>Satisfied through choice of CULT electives</td>
</tr>
<tr>
<td>Perspectives – Western Tradition</td>
<td>Satisfied through choice of CULT electives</td>
</tr>
<tr>
<td>Perspectives – Outside Western Tradition</td>
<td>Satisfied through choice of CULT electives</td>
</tr>
<tr>
<td>Service Learning – lower division</td>
<td>BMEN 2310</td>
</tr>
<tr>
<td>Service Learning – upper division</td>
<td>BMEN4030 &amp; BMEN4040</td>
</tr>
<tr>
<td>Interdisciplinary Scholarship (TIDES)</td>
<td>BMEN4030 &amp; BMEN4040</td>
</tr>
<tr>
<td>Capstone Experience</td>
<td>BMEN490x or BMEN491x</td>
</tr>
</tbody>
</table>

Table 2 - Undergraduate Core Requirements

Cultural Knowledge Electives

In the interest of making engineers more aware of their social responsibilities and better able to consider related factors in the decision-making process, coursework in humanities and social sciences is an integral part of our program. The BME curriculum requires a minimum of six courses of acceptable Cultural Knowledge electives in addition to satisfying the Freshman Year Writing requirement. Cultural Knowledge courses must be chosen to provide both breadth and depth and should not be a selection of unrelated introductory courses.

The specific requirements for choice of these electives are determined by Newcomb-Tulane College, and Biomedical Engineering students are urged to consult with the Newcomb-Tulane College Advising Center. While the BSE degree does not require a foreign language, it is highly recommended that students with a talent and background in languages consider using a language for some of the coursework to meet the Cultural Knowledge requirement. Engineering has become increasingly global, and a background in a foreign language and culture may be quite important to one’s career.

2.c.2 Domain Courses and Professional Electives

Each student must complete two Domain Courses and four Professional Electives. In order to satisfy the Domain requirement, each student must complete BMEN 3xxx courses in two separate Domains as listed in Table 1 above. In addition, one BMEN 6xxx follow-up course must be completed as a professional elective. The remaining three professional elective courses may be any courses that meet the student’s professional goals. Up to two ROTC courses may be used to meet this requirement.

2.c.3. or in Biomedical Engineering

For Engineering Majors

Students in Chemical Engineering or Engineering Physics may earn a Minor in Biomedical Engineering through completion of the following courses:

- CELL 1010/2115 Cell Biology
- BMEN 2600 Intro.to Organic and Biochemistries
- BMEN 3030/3035 Anatomy and Physiology for Engineers, with lab
- BMEN 3070/3075 Quantitative Physiology, with lab
- Plus 1 domain course selected from the list in Table 1

For Non-Engineering Majors

Students may earn a Minor in Biomedical Engineering through completion of the following sequence of courses. Students majoring in other Engineering fields should consult the department for an alternate list of requirements for the Minor.

I. Prerequisite Courses

- MATH 1210 Calculus I
- MATH 1220 Calculus II
- MATH 2210 Calculus III
- MATH 2240 Applied Math
- CELL 1010 Intro Cell Molec Biol (or approved substitute)
- PHYS 1310 General Physics I & Lab
- PHYS 1320 General Physics II & Lab

II. Engineering Courses

- Required of all Biomedical Engineering minors:
  - ENGP 1410 Statics
  - BMEN 2310 Product & Experimental Design
BMEN 3xxx “Domain” class

Any three courses chosen from the following list:
- ENGP 2010 Electric Circuits
- ENGP 2430 Mechanics of Materials
- BMEN 2020 Computing Concepts & App
- ENGP 3120 Materials Science & Engineering
- BMEN 2730 Biomedical Electronics & Lab
- BMEN 3440 Biofluid Mechanics

2.d. Undergraduate Teaching Facilities

2.d.1. BME Design Studio, SSE Building, room 208:
Designed as a multipurpose classroom/meeting/studio environment, the Department of Biomedical Engineering at Tulane University offers students the opportunity to experience the engineering design process from napkin-sketch concept to finished product. The studio is equipped with multiprocessor/twin-monitor workstations running the latest version of SolidWorks. CAD/CAM models can be molded in ABS plastic with the Dimension SST-1200 rapid prototyper, or milled in metal on the department’s CNC milling machine.

2.d.2 MakerSpace, SSE Building #125
The Department of Biomedical Engineering was the incubator of an extensive woodworking and machine shop environment that has been reorganized into a Maker Space facility which is now open to the entire Tulane community. Used extensively for undergraduate research, personal projects, and the BME Team Design curriculum, the Tulane MakerSpace provides a collaborative environment for:
- Fine/finish woodworking and patternmaking
- Thermoforming of plastics and PVC
- Working with GRP and composites, including vacuum-pressure molding
- Heavy/framing carpentry
- Light plastic and metalworking, machining

The MakerSpace has partnered with Tulane’s Studio Art program to allow welding to supplement our metalworking capability. Partnerships with commercial machine shops in the area can assist on projects that require additional tooling that may not be available on our own shop floor.
http://makerspace.tulane.edu

2.d.3 BME Computer Lab, Boggs 548:
Supporting the capabilities of the electronics laboratory is a digital classroom available for drop-in student use around the clock. The powerful workstation-class computers run Windows, a full complement of office productivity software, and specialized engineering applications. Students work with large 22" LCD screens to perform mathematical modeling, finite element analyses of their CAD/CAM models, or build custom LabVIEW interfaces.

2.d.4 Pendleton Lehde Electronics Laboratory, Boggs 539:
The Department of Biomedical Engineering operates an electronics design and testing facility to support graduate and undergraduate coursework and research. 10 workstations offer oscilloscopes, power supplies, prototyping boards, and circuit analysis software. Highlights of the lab include:
- National Instruments LabVIEW and MultiSIM software
- NI BNC-2120 A-to-D breakout boxes
- National Instruments ELVIS II development boards
- Biopac hardware/software suite for Physiology
- Arduino development environment

Typical applications/projects performed in the electronics lab include:
- Design and construction of embedded controllers
- Control of servo devices, robotics, display and sensor interfacing
- Work with rectifiers, filters, regulators and power supplies.
- Analog amplifiers and active filters of interest for medical devices.
- Combinational and sequential digital logic design techniques and circuits.

2.d.5 Teaching / Tissue Lab, Boggs 241:
This lab is a wet lab capable of holding large classes. It has a complete setup for cell culture work including laminar flow hoods, incubators, centrifuge, and water bath. It is also equipped for cell and molecular assessments, with phase/fluorescent microscopes, a gel imager, Admet test stand and fluorescent plate reader. This room is also equipped for tissue dissections and analysis. Multiple BME professors use this room for lab activities in a number of classes. In addition this room has significant bench top space and is ideal for large projects and group work.

2.d.6 C A M S, Reily Center:
The Center for Anatomical and Movement Sciences (CAMS) is one of eight specialized centers associated with the School of Science and Engineering. Its main goal is to provide anatomical resources to BME and other departments across the uptown
campus. CAMS main lab offers a unique human dissection experience to undergraduate and graduate students from the nine departments associated with the School of Science and Engineering (SSE).

Additional labs provide hands-on experience with accelerometry, electromyography, metabolic assessment, and spirometry and other movement related physiology.

2.e. Awards and Honors
There are many honors and awards that serve to recognize exceptional performance or service to the Department, the School of Science and Engineering, and Tulane University. These awards are given annually in a special ceremony. Some of these awards are recognized by a plaque permanently placed in the Departmental offices and on the Department’s web site. Details of past departmental awards can be found at http://tulane.edu/sse/bme/newsandevents/awards/index.cfm

2.e.1 University Honors for Academic Excellence
All Latin honors at Tulane are awarded on the basis of GPA alone. Student achieving a GPA in the top 30% of the class will receive Latin honors according to the following:

Summa cum laude = top 5% of the class
Magna cum laude = next 10% of the class
Cum laude = next 15% of the class

The precise GPA standards will be calculated based on the grades of the previous class.

Complete details of the requirements for university honors may be found https://honors.tulane.edu/content/honors-thesis-0

2.e.2 Scholarly Honors for Academic Excellence
Each BMEN student completes a year-long project as part of BMEN490x-491x. To be eligible for scholarly honors within Newcomb-Tulane College, a BMEN student must complete an honors project. Eligible students must normally have a cumulative grade-point average of at least 3.400 and a grade-point average of at least 3.500 in courses counting toward the major at the beginning of the academic year in which the thesis is to be started. If a student has a minimum overall GPA of 3.400 at the end of the junior year, and a minimum major GPA of 3.5, he or she may apply to convert the BMEN4900-4910 project to an honors project. Successful completion of this honors project and a qualifying GPA will result in the degree being conferred with Honors in Bio- medical Engineering.”

To apply for candidacy for this honor, the student must complete all of the following steps:

1) Select an honors thesis topic: Identify a suitable research topic through discussion with your faculty thesis advisor. Submit a letter to the instructor of Research and Professional Practice by March 15 of the third year declaring an aspiration to complete an Honors thesis. The letter should list a tentative title of the honors thesis and be signed by both the student and the faculty advisor.

2) Select a thesis committee: Select a research thesis committee that consists of at least three members from the academic, scientific, and professional community. The committee must include the student’s faculty advisor. At least one member of the committee should be of the BMEN departmental faculty and at least one member should be from outside the BMEN department.

3) Declare the intention to complete an honors thesis: The student should declare the intention to complete an Honors thesis by submitting a prospectus to the instructor of Research and Professional Practice and to the Dean of the Honors Program by September 30 of the fourth year. The prospectus must be signed by the student and the entire thesis committee.

4) Submit a thesis to the BMEN department: Complete a thesis suitable for honors and signed by the student and all committee members. The thesis should be submitted to the instructor of Research and Professional Practice by the final day of class (before the reading period) of the fall semester of the fourth year.

5) Perform a public defense: Present a student-scheduled seminar and defense of the thesis that is open to the general public and attended by the thesis committee by April 10 of the fourth year. Successful completion will result in a signature by all committee members on the Honors Program Oral Defense form, which must be delivered to the Honors Program office.
6) Submit the thesis to the Honors Program: Submit a copy of the final thesis, formatted correctly and with the requisite signatures, to the Honors Program Office by the final submission deadline (usually about 10 days before the date of Commencement). For formatting and deadline information consult with the Honors Program Office.

Following successful completion of all the Honors thesis requirements, Scholarly Honors will be recognized at the Honors Program Senior Reception, at Commencement, and on the student’s diploma. For participating in the fifth year program, requirements #4-6 (submission of thesis and public defense) will be satisfied by the completed Master’s Thesis.

2.1 Post-Graduation Career Paths
Every class is composed of outstanding individuals—BMEN students are typically some of the brightest students on campus, and each class seems to develop its own personality and interests. Thus, answering the frequent questions about expected post-graduation plans for beginning students is difficult. However, because biomedical engineering is a new and dynamic field, the questions about “what can I do with the degree” are frequent. The following observations are offered to give some insight, but these are generalizations and should be regarded as such.

Each year, approximately one half of the entering BMEN Freshmen have—at least in the back of their minds—the idea that they may want to go to medical school to become a practicing physician. Typically, at the end of four years, slightly more than one third of the class members enter graduate school, and approximately 20% of the class members enter medical school. Of the remaining students, some begin their military commitment following ROTC training, and others (one-quarter of the class) enter the workforce. Jobs are typically available in government (e.g., FDA, NASA) or the medical device industry (e.g., orthopedic appliance companies, pacemaker companies). The high percentage of students who choose to continue their education is primarily driven by the students’ desire to participate in the discovery and innovation that characterizes the growing field of biomedical engineering. In addition, although there are approximately 10,000 medical device companies in the US, the companies tend to be quite small so that students seeking employment must aggressively seek job opportunities. Help is provided by the Career Services Center and by the informal network of industry links from faculty and alumni.

Students are encouraged to work with Tulane’s Career Services Center (http://hiretulane.com) to find internships and employment opportunities. BMEN alumni who are willing to answer current students’ questions about employers and career paths can be found on our alumni web group.

http://www.linkedin.com/groups?gid=1923837

2.1.1 Pre-Medical Information
Earning an undergraduate degree in Biomedical Engineering provides an excellent foundation for eventually becoming a practicing physician. The training in quantitative reasoning and problem solving is particularly valuable in forming diagnoses and treatment strategies. In addition, the required year-long Anatomy and Physiology sequence during the junior year (taught by the medical school faculty), provides a solid introduction to physiology. The BMEN students have a fine record of acceptance into medical school—typically at least twice the national average. However, the rigorous engineering curriculum is a difficult pathway to medical school—especially if the student does not have a fundamental and driving interest in becoming an engineer. If a student really only wants to be a physician and does not have interests that are quantitative and technical, another choice of a pre-med major is recommended.

The standard biomedical engineering curriculum comes close to meeting the admission requirements for many medical schools. Each medical school establishes its own required sequence of courses and students need to check with the specific school of interest and also meet with Tulane’s pre-med advisor to carefully plan the appropriate courses (http://advising.tulane.edu). In general, pre-meds must supplement the Tulane BMEN standard curriculum in three areas:

**English:** Many medical schools require a year of college English, but BMEN requires only one semester. One of the Cultural Knowledge electives can be used for the second semester of English.

**Biology:** Most medical schools require a year of college Biology, with Lab. The BMEN curriculum requires one semester (with lab) supplemented by the year-long sequence of Anatomy and Quantitative Physiology. Although this standard sequence exceeds the Tulane Medical School requirements for “biological sciences” most other schools will require an additional course in general biology.
second biology course may be taken and counted as a professional elective.

**Organic Chemistry:** The standard BMEN curriculum does not require Organic Chemistry. All medical schools require a year-long sequence in Organic Chemistry, with Lab. Tulane BMEN students may use two professional electives to take Organic Chemistry. Many students find it advantageous to take Organic Chemistry during the summer between their Sophomore and Junior years. The required course, BMEN 2600, Introduction to Organic and Biochemistries, does not count toward the medical school requirements, but is required by all BMEN students in preparation for the Quantitative Physiology sequence. Students may elect to substitute a two-semester course in Organic Chemistry and a one-semester course in Biochemistry (CHEM3830 or CELL 4010) in lieu of BMEN 2600. The biochemistry course does not constitute a professional elective.

**2.f.2 Teacher Certification**

Through judicious selection of electives, it is possible to complete a sequence of courses that leads to certification as a secondary school Math and Physics teacher. This option is fully described at [http://bit.ly/QdRJ84](http://bit.ly/QdRJ84)

additional information about the University’s teacher certification program is at [http://teacher.tulane.edu](http://teacher.tulane.edu)
An integrated five-year Bachelor’s - Master’s program is available in the School of Science and Engineering wherein students pursue both the BSE (Bachelor of Science in Engineering) and MS (Master of Science) degrees. Management of the program—including specific eligibility requirements—is determined by the various Departments subject to the approval of the School of Science and Engineering.

3. BSE-MS Program

3. Options for Biomedical Engineering Students
The Biomedical Engineering Department has a program leading to both the BSE and MS degree in five years. Participation requires a current undergraduate student to apply and to be accepted.

The 5 year plan allows a student to elect not to receive a BSE until the end of the fifth year, then both degrees are awarded. This plan has two attractions:

1) The student maintains an undergraduate status with potential benefits of certain scholarships or other financing
2) A separate senior thesis is not required.

Completing the Master’s thesis serves in lieu of a senior thesis.

Tuition for this program is 35% of the normal full graduate tuition during the fifth year.

3. Initial Eligibility Timeline

- Minimum 3.4 GPA at the conclusion of the 1st semester of the Junior year. For this GPA the student may include his or her transfer credits. Official transcripts do not always include transfer credits into the calculation of an individual’s GPA and may not be a complete representation of the total GPA for courses taken towards an individual’s degree.
- Identification of an advisor willing to supervise the student and a focused research plan, as indicated by a letter of intent to the instructor of Research and Professional Practice. This letter is needed by March 31st of the 3rd year. The letter of intent, co-signed by the advisor, report the student’s current cumulative GPA and should briefly describe an appropriate research topic and project to be completed.
- Students not meeting the above requirements (individuals with a GPA between 3.0 and 3.4) may file a letter of intent that includes a petition to the Department to participate in the five year program. This is due by March 31st of the 3rd year.

3. Continuation Requirements

- Formal application to the school’s graduate division is due in the Department by October 1st of the 4th year. The application must be complete and include a transcript, essay, and GRE scores (minimum combined total of Verbal and Quantitative of 310). If the prospective MS thesis advisor is a member of the regular BMEN faculty, then the applicant only needs to submit a letter of support from his or her research advisor. Otherwise, three letters of recommendation are needed.
- An admission decision will be made by the Department by November 1st of the 4th year. The approved students will then be formally admitted to MS candidacy following the standard policies of the Graduate Division of the School of Science and Engineering.
- Students who have been approved for participation will then be required (or optional at advisor’s recommendation) to drop BMEN 4910 Research and Professional Practice II (without record) and add BMEN 4930 Advanced Undergraduate Research in order to meet undergraduate degree requirements. This schedule change will allow 5th Year students to more effectively concentrate on their research projects in lieu of completing the course requirements of BMEN 4910. The grade for BMEN 4930 will be listed as In Progress (IP) until such time as the master’s thesis is completed, whereupon the student’s advisor and thesis committee will assign a grade necessary to fulfill bachelor’s degree requirements.
- Students may use 6 credits of Tulane BMEN3xxx courses towards fulfillment of the 24-credit requirement for the MS degree. These same 6 credits can also count towards the BSE degree. A grade of “B” or better must be earned in the courses that are counted towards both degrees.

Most students will use BMEN 3030 and 3070 towards the MS course distribution requirements.
3.d. Degrees

- Participation in commencement ceremonies is governed by the standard policies of the School of Science and Engineering.
- Upon successful completion of all BSE and MS degree requirements, assuming the student has not already received the BSE degree, the student graduates at the end of the term in which the requirements have been fulfilled with both degrees (BSE and MS).
- If BSE requirements are not met (because the thesis is not complete), but if all undergraduate course requirements have been fulfilled, the student participates in commencement at the end of the 4th year by being recognized with a certificate of accomplishment, but does not receive a BSE degree.

3.e. Timing and Financial Support

Considerations

- Tuition during the 5th year is discounted by the School of Science and Engineering to be 35% of the normal full-time graduate tuition. Note that scholarships and other financial aid will not normally be continued during the 5th year; financial need is most often met in the form of low-interest student loans.
- Students pursuing this program are strongly encouraged to spend the summer between the 4th and 5th years doing research on their project. Occasionally, summer funding may be available from the student's advisor or other sources of support. In order to receive support from Tulane, the student must be registered.
- After the 5th year, students may, if necessary continue for an additional ½ academic year to complete the degree without additional charge. After this grace period, tuition would be charged at 35% of the graduate tuition rate per credit.
Discoveries emanating from Biomedical Engineering research programs have been a source of pride at Tulane for more than 50 years. The first doctorates for Biomedical Engineering research were awarded in the early 1970s, and our research labs continue to host a diverse group of undergraduate, Master’s, and Doctoral students working with faculty mentors.

4.a. Graduate Program Instructional Objectives
We enhance the academic preparation of our graduate students in engineering, mathematics, and the life and basic sciences. Our graduate students are our junior colleagues, and we furnish them with the advanced and current coursework, professional guidance, and equipment/facilities that are critical to their participation in biomedical engineering research and scholarship. We coach our students as they conduct independent research and pursue careers related to one of the major themes of biomedical engineering (e.g., biomechanics, bioelectronics, biomaterials, biotransport, bioelectricity, or cell/tissue engineering).

4.b. Programs of Study
The Department of Biomedical Engineering offers courses of study leading to the Master of Science (M.S.) with thesis and non-thesis options and the Doctor of Philosophy through the Graduate Division of the School of Science and Engineering. The Master’s degree requires 24 semester hours of approved course work including at least one advanced mathematics course and at least one graduate-level course in each of the following subjects: biomechanics, bioinformatics, bioelectricity, and biomaterials or tissue engineering. Also required is an approved thesis, or, by petition to the faculty, 30 hours of approved course work for the non-thesis option.

Tulane also has an integrated 5th year master’s program to allow our best qualified undergraduates the opportunity to complete a two-year master’s level research project by building upon the undergraduate individual research project. Students may then be able to complete all requirements for the bachelor’s and master’s degree in five years (usually including the summers after the 4th and 5th years), although some take longer.

4.b.1. Application and Admission
Applications for admission to the PhD program are due by January 1 for the following Fall semester. Admission in the Spring semester generally requires an approved prior arrangement. Applications for the non-thesis MS program are due March 1 for the following Fall semester, and August 1 for the Spring semester. Applicants must hold a bachelor’s degree to be admitted, and are required to submit transcripts of prior work and three recommendation letters. Recommendation letters must be signed, printed on an institutional letterhead, and sent from an institutional email address. All applicants must take the Graduate Record Exam (GRE). Only the general test is required.

Information about the department, including application instructions, an application form and recommendation forms are available at http://www2.tulane.edu/sse/bme/academics/graduate/prospective/application-process-and-checksheet.cfm

4.b.2. Tuition and Expenses
Tuition for the 2017-2018 academic year
https://studentaccounts.tulane.edu/content/ tuition-and-fees
Student Health insurance
http://campushealth.tulane.edu/insurance-fees/t-ship ~50% of which is subsidized for students supported through fellowships teaching assistants or research assistants. Students who have completed their coursework requirements are required to register for Master’s Research 9980 (3 credit hours) or Dissertation Research (BMEN 9990 (3 credit hours) in order to maintain continuous registration. Tuition equal to one 3 credit hour course and part time fees will be assessed for this registration. Living expenses for the single student are approximately $7,000
https://www2.tulane.edu/financialaid/cost/gradprofc oa1718.cfm. For international students, these fees are higher due to foreign travel costs, insurance, and initial household expenses. Graduate student housing is available in Tulane University apartments on a limited basis, though most students rent apartments near the university.

Tuition for both the Non-Thesis Masters, and Thesis program in the Department of Biomedical Engineering is offered at a rate of 50% of the undergraduate tuition. The tuition for this program is limited to one year of tuition if the student completes his/her coursework in less than 18 months. After that, additional tuition will be charged one-half of the prevailing
credit-hour rate (https://studentaccounts.tulane.edu/content/tuition-and-fees). Part-time students will be charged tuition at one-half of the prevailing credit-hour rate.

4.b.3. Financial Support

The Department of Biomedical Engineering provides merit-based aid to support our graduate students in paying for the cost of graduate education. Recipients of merit-based financial aid are chosen solely on the basis of academic qualifications. The stipend for incoming students entering in Academic Year 2017-2018 is $27,000 for 12-months in residence plus 50% semester credit for a Tulane-sponsored health insurance plan. Ph.D. students are given priority for merit-based aid, and students pursuing the non-thesis option Master's degree are ineligible. The forms of merit-based aid are:

Incoming Awards

Teaching assistantships (TA)
The department’s primary method of support for incoming graduate students is through Teaching Assistantships. A Teaching Assistant is assigned to assist a faculty mentor and shares teaching responsibilities. TA duties may include discussions about upcoming lectures, feedback from lectures, and the preparation of handouts, grading, and laboratory instruction. The TA generally attends all class meetings.

Fellowships

These fellowships are primarily awarded by the Louisiana Board of Regents through Tulane University, and generally provide four-years of support plus a tuition waiver. Recipients must be U.S. citizens or resident aliens.

Continuing Awards

Research assistantships (RA)
These assistantships pay a stipend that is individually determined, and include a tuition waiver. These awards may be given to continuing graduate students who are performing research projects on a topic with extramural financial support.

4.c. Program for Students without an Engineering Degree

A special program has been developed for those with a B.S. or B.A. in non-engineering disciplines who wish to earn a degree in Biomedical Engineering. The entrance requirements are: (1) an undergraduate degree with substantial science content including a year of calculus, a year of physics, a year of biology, and a year of chemistry; (2) an undergraduate grade average of “B+” or better (e.g. 3.3). The program normally takes at least two years as follows:

First Year: The student enrolls in the undergraduate division of the School of Science and Engineering as a non-degree-seeking student. The courses taken during the first year are typically the following, although the specific selection may be tailored to the student’s background if some of the following have already been satisfied:

<table>
<thead>
<tr>
<th>Fall Semester</th>
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<tbody>
<tr>
<td>MATH 2210</td>
<td>Calculus III</td>
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<tr>
<td>BMEN 2310</td>
<td>Product and Experimental Design</td>
</tr>
<tr>
<td>ENGP 2010</td>
<td>Electric Circuits</td>
</tr>
<tr>
<td>ENGP 2430</td>
<td>Mechanics of Materials</td>
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</tbody>
</table>

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<tr>
<th>Spring Semester</th>
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<tbody>
<tr>
<td>MATH 2240</td>
<td>Introduction to Applied Math</td>
</tr>
<tr>
<td>BMEN 2730</td>
<td>Biomedical Electronics and Lab</td>
</tr>
<tr>
<td>ENGP 1410</td>
<td>Statics</td>
</tr>
<tr>
<td>BMEN 2020</td>
<td>Computational Concepts and Applications</td>
</tr>
<tr>
<td>ENGP 3120</td>
<td>Materials Science and Engineering</td>
</tr>
</tbody>
</table>

These courses do not count for credit towards a graduate degree. Academic performance in these courses determines whether the student is admitted to the undergraduate or graduate division at the beginning of the second year.

Second Year: Students who complete the courses listed above with a grade point average of 3.00 or better may transfer into Graduate Division of the School of Science and Engineering to work on the M.S. degree. During the second year, the student must also pass BMEN 3440, Biofluid Mechanics, which does not count for graduate credit. Students who complete the courses listed above with a grade point average of less than 3.00 are given the option to apply to the undergraduate division of the School of Science and Engineering to complete the Bachelor's degree as a transfer student.

4.d. Requirements for Advanced Degrees

The following curriculum is generally taken as an undergraduate prior to matriculation to Tulane’s BME graduate program (course numbers are equivalent Tulane courses satisfying each requirement)

1 year of college physics (PHYS 1310-1320)
1 year of college chemistry (CHEM 1070-1080)
1 semester of biology with lab (CELL 1010)
1 course in computer programming (BMEN 2020)
3 semesters of calculus (MATH 1210-1220, MATH 2210)
4.d.1. Requirements for the Master's Degrees

1.) Non-Thesis Master of Science
A non-thesis Master of Science degree (MS) is offered by the Graduate Division of the School of Science and Engineering upon the completion of 30 semester hours of approved graduate course work. This coursework must satisfy the distribution requirement (see below). Students receiving aid in the form of a teaching assistantship or a research assistantship are generally not eligible for a Master's degree as their terminal degree. Doctoral students that have completed 30 semester hours of approved graduate credit and who have successfully defended their research prospectus may then petition the Department for a non-thesis MS degree. Tuition is set at 50% of regular full graduate division for students in the terminal non-thesis MS program.

2.) Thesis Master of Science
The basic requirement for a Master of Science (MS) degree in Biomedical Engineering is completion of 24 hours of approved graduate level coursework that satisfy the distribution requirement (see below) and the writing of a scholarly thesis representing original research. The thesis committee must consist of at least three members, two of whom must be full-time members of Tulane's faculty and a chairperson who is a full-time faculty member in the Department of Biomedical Engineering. The thesis MS is typically available only by special arrangement or as a 5th year program (see section 3.)

3.) Course Distribution Requirements for Master's Degree
In order to prepare our students for careers in biomedical engineering, which is a rapidly evolving interdisciplinary field, we require all graduate students to complete a distribution of classes. These are:

- a. Anatomy and Physiology
  BMEN 6030/6035 Anatomy and Physiology for Engineers with Lab, and
  BMEN 6070/6075 Quantitative Physiology with Lab.

- b. Biomedical Engineering Domains
  One course each in three of the four domains, as described in **Table 1**.

- c. Mathematics
  One course in advanced mathematics (e.g., various 6000-level MATH courses)

4.d.2. Requirements for the Doctoral Degree
The Ph.D. is an academic degree that prepares students for careers in teaching and research. A Master's degree is not required for students seeking the Doctoral degree. The specific requirements are as follows:

1.) Distribution Requirements
- a. Anatomy and Physiology
  BMEN 6030/6035 Anatomy and Physiology for Engineers with Lab, and
  BMEN 6075/6075 Quantitative Physiology with Lab.

- b. Biomedical Engineering Domains
  One course in three of the four domains, as described in **Table 1**. Only one (1) of the domain requirements may be satisfied through the completion of a BMEN 3xxx/6xxx domain course

- c. Mathematics
  One course in advanced mathematics (e.g., various 6000-level MATH courses)

2.) Coursework
The student must demonstrate superior performance while completing 48-hours of graduate study with nine in-class "didactic" classes completed

(see **Table 3**).
the request semester

The more their per time"

must regardless
demonstrate pursuing
In addition

Notes:
- All graduate students must register for, and attend, BMEN 6710 Research Seminar.
- A maximum of 15 of the 48 required credit hours may be taken as BMEN 7220 Directed Readings or BMEN 7310-7320 Research in BME. Students transferring to Tulane may transfer a maximum of 24 credits, and must complete at least 18 in-class credit hours of graduate study at Tulane University.

3.) Teaching Experience
In addition to the coursework and research requirements described in detail below, all students pursuing a Ph.D. in Biomedical Engineering must demonstrate teaching competence as part of their training toward the degree. All doctoral students - regardless of their financial support package must serve as a TA for at least one semester prior to completion of their Ph.D. program.

Teaching Assistantships are regarded as "one-third-time" appointments and average about 12-15 hours per week of effort. TAs attend all classes taught by their faculty mentor, and are permitted to enroll in no more than 3 courses per semester.

4.) Qualifying Exam
The qualifying exam is usually taken after the fourth semester of graduate study, although students may request that it be taken earlier by written petition to the departmental faculty. The exam is a rigorous test of scholarly competence and knowledge, and is conducted as an oral examination.

The qualifying exam (QE) is given annually in May/June. In order to take the QE, the prospective PhD candidate must submit a petition to the Director of Graduate Studies by February 15. The petition should include:

1) A copy of the candidate's transcript. Petitions will only be guaranteed for acceptance if the candidate demonstrates that they will, at the time of the exam, have completed course requirements #1-6 in Table 3, and that they have a cumulative GPA of 3.5 or above in these courses.

2) A document (no more than 1 page long) that describes the student's Ph.D. research area. This document should also list three relevant graduate courses that the student has completed and explain how the sub-disciplines related to these courses have prepared the student to begin independent advanced study in their Ph.D. research area.

The Department's Graduate Committee will review each petition. Upon acceptance of the petition, the Graduate Committee, in concert with the student's primary advisor, will assign a qualifying examination committee. At least three of the committee members must be department-affiliated full-time faculty.

The prospective PhD candidate is encouraged to initiate a meeting with his/her committee prior to the exam wherein a broad overview of the content areas

<table>
<thead>
<tr>
<th>#</th>
<th>Description of Requirement</th>
<th>Credit Hours</th>
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<tbody>
<tr>
<td>1</td>
<td>Anatomy and Physiology with Lab (BMEN 6030/6035)</td>
<td>3 + 1</td>
</tr>
<tr>
<td>2</td>
<td>Quantitative Physiology with Lab (BMEN 6070/6075)</td>
<td>3 + 1</td>
</tr>
<tr>
<td>3</td>
<td>Advanced mathematics</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>Domain Distribution (see Table 1)</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>One course each in 3 of 4 domains</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>Maximum of 1, 3xxx-6xxx cross-listed domain courses</td>
<td>3</td>
</tr>
</tbody>
</table>

Total credits required to petition to take PhD qualifying exam: **20**

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<th>Description of Requirement</th>
<th>Credit Hours</th>
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<tbody>
<tr>
<td>7</td>
<td>Elective course 1</td>
<td>3</td>
</tr>
<tr>
<td>8</td>
<td>Elective course 2</td>
<td>3</td>
</tr>
<tr>
<td>9</td>
<td>Elective course 3</td>
<td>3</td>
</tr>
</tbody>
</table>

Minimum of elective course credits required: **9**

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<tr>
<th>#</th>
<th>Description of Requirement</th>
<th>Credit Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Research Seminar (BMEN 6710 – register every fall), maximum</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>credits allowed</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Remaining 15 credits may be satisfied by BMEN 7310-7320</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Research in BME (graded), Directed Readings, or didactic courses</td>
<td></td>
</tr>
</tbody>
</table>

Total: **48**

Table 3: Course Requirements for a Ph.D. in Biomedical Engineering
will be discussed. This discussion will not provide an exclusive list of topics; rather, it will offer a framework for the student’s preparation.

The oral exam will commence with a brief (~5 minute) presentation by the prospective Ph.D. candidate in which (s)he will present the content of the qualifier petition document (item 2). The exam will continue with questions by the committee that will be free-ranging, and will be used to identify a candidate’s strengths and weaknesses in his/her field of interest.

The criteria for passing the exam will include what the faculty determines to be the required minimum competence. The student will be informed of the results of the exam by June 15, with the following possible outcomes:

a. Pass (and possibly recommendations)
b. Conditional Pass (with specific requirements)
c. Fail with encouragement to retake the exam
d. Fail with conversion to the MS

Upon completion of this requirement, the student is admitted to candidacy for the doctoral degree. If the examination is failed, it may be retaken once only. A student who fails the exam twice will not be admitted to Ph.D. candidacy, although the student may then proceed with the Master’s Degree.

5.) Prospectus and Prospectus Examination
This is an oral examination in depth on specific topics of the candidate’s intended research, and includes the preparation of a written prospectus of the proposed dissertation research. It is administered after the student has passed the Qualifying Exam, and should be completed during the third year of study. In Biomedical Engineering, the student is required to satisfactorily prepare a written prospectus on his/her dissertation topic in addition to the three-page prospectus required by the Graduate Division. The proposed prospectus should present an overall plan for the dissertation research, which may change during the progress of the dissertation with the approval of the thesis committee. The format should follow the prospectus requirements:

- Abstract (1-2 paragraphs): Executive Summary
- Specific Aims (1 page): Specific Aims are not necessarily hypothesis-driven
- Background and Significance: (3-5 pages) Includes motivation and key references
- Research Project Description (6-10 pages): The specific format of this section is ad libitum, but it should address the research approach (including preliminary studies, if any) that will provide experimental and/or theoretical support of the proposed specific aims.

- Timeline (1 page)
- References

The prospectus will be presented to the student’s 3-member (minimum) dissertation committee. At least three committee members must be full-time faculty members at Tulane and the committee chair must be a full-time member of the Department of Biomedical Engineering.

6.) Dissertation and Defense
The dissertation is an original contribution to the field. The entire dissertation, or parts of the dissertation, should be of a quality suitable for publication. The candidate must pass the final, public oral examination, which is a primarily a presentation and a defense of the dissertation.
4.e. Research Domains
Tulane’s Department of Biomedical Engineering has a long history of studying a wide variety of research problems using traditional engineering expertise to analyze and solve problems in biology and medicine. Our program has particular expertise in the following biomedical engineering domains:

**Biomaterials** includes both living tissue and artificial materials used for implantation and to foster cell function. 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 is a complex task, with newer biomaterials incorporating living cells in order to provide a true biological and mechanical match for the living tissue. Research in this area is conducted by Dr. Moore, who studies neuro-generation primarily of the optic nerve.

**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 and flows. These can influence the macro-scale and micro-scale stresses that can impact biological function at the organ, cell, and subcellular level. Research in this area is conducted by Drs. Anderson, Gaver, Khismatullin, Miller.

**Biosignals and Bioimaging** includes biological signal measurement, analysis, and modeling. Signals generated through interaction of various forms of energy with living systems can be recorded with specialized instrumentation and rendered as an image for further processing and analysis. Areas of interest in this domain include bioinformatics, biomedical acoustics, biophotonics, diagnostics and therapy, medical imaging, and molecular imaging. Research in this area is conducted by Drs. Bayer, Brown, Bull, Khismatullin, and Wang.

**Biotransport** relates to physical and biological processes that govern molecular and convective transport of substances within biological systems. These transport processes may be passive (convection, diffusion) or active (such as with sodium-potassium pumps), wherein energy is expended to move material against a concentration gradient. Research in this area is conducted by Drs. Gaver, Khismatullin.

**Cell and Tissue Engineering** utilizes the anatomy, biochemistry and mechanics of cellular and subcellular structures in order to understand disease processes and to intervene at very specific sites.

With these capabilities, bio-mimetic structures can be fabricated and investigated to understand the basics of physiological (dys) function, or devices can be designed and used to deliver chemical, mechanical or electrical stimuli that can influence cellular processes at precise target locations. This can develop knowledge related to physiological processes in development and disease, or can lead to therapies in regenerative medicine to promote healing or inhibit disease formation and progression. Research in this area is conducted by Drs. Gaver and Moore.

**Design** is the application of mechanics, materials, and electronics to develop devices used in diagnosis and treatment of disease. Computers are an essential part of bioinstrumentation, from the embedded controller in a single-purpose instrument to the multi-core array needed to process the large amount of information in a medical imaging system. Microfluidics allows manipulation and analysis of minute amounts of biological samples, and thus enables the design and fabrication of low-cost, miniaturized devices for point-of-care clinical diagnostics. Research in this area is conducted by Drs. Anderson and Gilbertson.

4.f. Research Laboratories
A brief summary of the current work of each research-active faculty member appears below. Most graduate students choose to work in one of these laboratories. Opportunities also exist in labs at the medical schools of Tulane University and Louisiana State University, both in downtown New Orleans.

**Biomedical Functional Imaging Laboratory**
- **Dr. Carolyn Bayer**

Research in the Biomedical Functional Imaging Laboratory develops novel medical imaging methods to study the dynamics of molecular expression and physiological function. In our work, we integrate ultrasound and contrast-enhanced photoacoustic imaging systems, including the development of algorithms for functional and molecular photoacoustic imaging and the evaluation of photoacoustic and ultrasound contrast agents. A key focus of our imaging technology is the functional and molecular environment during compromised pregnancies and the development of birth defects. We search for new methods to treat these conditions through the knowledge gained through our functional and molecular imaging technologies.
Biomedical Acoustics Lab - Dr. Damir Khismatullin
Using in vitro and in vivo experimental systems, the Biomedical Acoustics Laboratory studies how living cells, tissues and biological polymers respond to mechanical stresses induced by acoustic waves (including ultrasound). This research on acoustic mechanotransduction has several important biomedical applications, and the current focus of the laboratory is on development of ultrasound-based noninvasive or minimally invasive therapies for cancer, spinal cord injury and neurodegenerative diseases.

Biofluid Mechanics Lab - Dr. Jim McManus
The Biofluid Mechanics Laboratory at Tulane University studies the interrelationships between fluid mechanical and physicochemical phenomena and the associated biological behavior of physiological systems. The main thrust of this research involves investigations of the pulmonary system, with the goal of developing improved therapies for pulmonary disease ARDS and the prevention of ventilator-induced lung injury (VILI). In addition, we investigate the design of optimized microfluidic devices for biosensor technology. These integrated studies bring together basic and applied scientists (including computational scientists), device developers and physicians to study problems of high clinical importance.

Translation Biophotonics Lab – Dr. Quincy Brown
Research focuses on the application and translation of quantitative spectroscopy and imaging tools for the improvement of cancer management in the clinical setting. We develop translatable optical methods to directly address gaps in clinical care, and carry those through to clinical validation in humans alongside our physician collaborators. A major theme in this work is the use of spectroscopy and imaging devices to improve patient outcomes in surgical tumor removal in a number of organs including the breast, prostate, and kidney. We also develop tools and strategies using optics to answer interesting biological questions in cell and animal models (for example, imaging of tumor hypoxia and metabolism).

Biotransport & Ultrasound Lab – Dr. Joe Bull
Our lab’s research focuses on biofluid mechanics and ultrasound, including theoretical and computational modeling, and in vitro and in vivo experiments. Our work in gas embolotherapy is focused on developing this potential treatment for cancer and addressing related fundamental questions. Gas embolotherapy involves injecting perfluorocarbon liquid droplets into the bloodstream and then selectively vaporizing them to form gas bubbles that occlude blood flow and/or deliver drugs to tumors. Diagnostic applications of selectively formed microbubbles are also of interest. Other work in our lab centers on the cardiovascular and pulmonary systems, related biomedical devices, and edema.

Cellular Biomechanics and Biotransport Lab - Dr. Damir Khismatullin
Using a combination of advanced experimental techniques and state-of-the-art computational models, the Cellular Biomechanics and Biotransport Laboratory studies the mechanical properties of living cells and develop novel, optimized approaches for treatment of cardiovascular disease, diabetes and cancer. Some of the current projects in the laboratory include: 1) Endothelial dysfunction and circulating cell-endothelium interactions in cancer, atherosclerosis, thrombosis, and diabetes; 2) Modeling of spreading, contraction, and active migration of leukocytes and cancer cells; 3) Novel methods for rheological characterization of biological materials; and 4) Patient-specific computational modeling of aneurism and plaque rupture.

The Biomechanics of Growth & Remodeling Lab - Dr. Kristin Miller
The Biomechanics of Growth & Remodeling Laboratory uses a combined experimental and computational approach to better understand, describe, and predict soft tissue remodeling in response to various chemo-mechanical stimuli including normal processes (e.g., aging and pregnancy), disease, and injury. To this end, our research utilizes model systems with varying restraints on regenerative capability (postnatal development, pregnancy, and postpartum) to define local microstructure and mechanical properties of evolving collagenous tissues to identify potential treatments and the appropriate timecourse for clinical interventions to prevent maladaptive remodeling, improve adult response to injury, and advance tissue engineering strategies. Our primary areas of research include orthopaedics (tendon and ligament) and women’s reproductive health.

Neural Microengineering Lab – Dr. Michael Moore
Our group utilizes tissue engineering and related technologies for the study of central nervous system (CNS) regeneration and development of treatments for CNS disorders. In particular, we are interested in the relationship between the three dimensional architecture of regenerating CNS tissue and its functionality. The major experimental goals in our laboratory are to: 1) design and fabricate biomaterial constructs with specified structural and molecular microarchitectures and employ 3D tissue culture preparations and 3D microscopic imaging for evaluation of constructs; 2) design and evaluate drug delivery systems for promotion of CNS axon regen-
eration; 3) develop implantable materials for CNS tissue engineering and evaluation in small mammals.

**Multiscale Bioimaging and Bioinformatics Lab**
*Dr. Yu-Ping Wang*

The Multiscale Bioimaging and Bioinformatics Laboratory has three research themes: 1. Fundamental research on multiscale signal/image representation and analysis; 2. Multiscale bioimaging analysis from organ and tissue levels to molecular and cellular levels; and 3. Bioinformatics in human genomics and cytogenetics. Currently, we are working on information extraction and integration from multiscale and multimodality genomic imaging data. One of our goals is to bring the biomedical technique into commercial use. We are using a multidisciplinary approach and working closely with computational scientists, statisticians, medical geneticists and industrial engineers at Tulane Medical Center and all over the world.
4.g. Core Lab Facilities
In addition to the individual faculty research labs, the Biomedical Engineering Department maintains several shared facilities for use by the members of our department in the Lindy Boggs Building on the uptown campus and the James Bennett Johnston (JBJ) Building on the Health Sciences campus:

**Tissue Culture Core Lab, JBJ**
The TCC Lab is fully equipped for cell/tissue culture and a range of cellular, molecular and chemical assays, as well as microscopy techniques. We maintain equipment including laminar flow hoods, refrigerated centrifuge, autoclave, incubators, vacuum aspiration systems, fluorescent microscope, water filtration systems, refrigerators and freezers.

**Microscopy Suite, JBJ**
The Microscopy Suite houses a Nikon TE-2000i fluorescent microscope with spinning disc confocal system. The semi-automated microscope utilizes a software program to help analyze the data captured. The room is stocked with other useful supplies like syringe pumps and a stereoscope to assist with your visualization needs.

**Supply Center, Boggs 547**
The Supply Center houses the department Ultralow Freezer, glassware washer, DI water source, and industrial sink. This room also houses the Invitrogen Supply Center and members of the Uptown Tulane campus come here to purchase common lab supplies as well as Invitrogen Products.

**Teaching Lab, Boggs 241**
The Teaching Lab is a wet lab capable of holding classes. It has a complete setup for cell work including laminar flow hoods, incubators, centrifuge, and water bath. All BME professors are able to use this room for lab activities in their classes. This room has significant bench top space and is ideal for large projects and groups.
Courses in Biomedical Engineering

A course with a four-digit number, such as 1010, lasts for one semester. A course with a double number, such as 1010-1020, lasts for both semesters. Courses with numbers from 1000 to 1990 are ordinarily open to freshmen; 2000 to 2990 are ordinarily open to sophomores; 3000 to 3990 are ordinarily open to juniors; 4000 to 4990 are ordinarily open to seniors; 6000 to 6990 are generally open to advanced undergraduate and graduate students unless marked with a § which indicates that the course is only open to graduate students; and 7000 to 7990, to graduate students only. An asterisk * denotes a less frequently offered class.

2020 Computing Concepts and Applications (4)
Dr. Sanchez
This course introduces students to the foundations of algorithm development and programming, basics of matrix algebra and numerical analysis, solving ordinary differential equations.

2310 Product & Experimental Design (3)
Dr. Brown.
The objective of this course is to introduce students to the design process as they are starting the BMEN Curriculum. Through team projects geared toward translating bench research into product development, students will be challenged to begin thinking critically and applying physical fundamentals to complex systems. Weekly lectures will highlight phases of the design process, including problem identification, conceptual design, and early prototyping. Additionally, in the context of product and experimental design, students will gain experience with computer aided design and be provided an introduction to statistics. Course restricted to BMEN majors, or by permission of the instructors.

2600 Introduction to Organic and Bio-Chemistries (3)
Staff
Prerequisite: CHEM 1080 and CHEM 1085, or approval of instructor
This course introduces the main principles of Organic Chemistry and Biochemistry, preparing the student for BMEN 3030/3040. Topics include nomenclature of organic compounds and bio-molecules, major reactions of organic chemistry, relationship between chemical structures and biological functions, and the reaction pathways of major metabolic processes. Students will be introduced to the three-dimensional structure of organic compounds and biomolecules using molecular models and software tools.

2730 Biomedical Electronics with Lab (4)
Prerequisite: ENGP 2010

3010/6010§ - The Physical Dimensions of Aging (3)
This course is designed to introduce students to the physiological, behavioral, and socioeconomic changes associated with aging. In particular, we will focus on what physiological and structural changes are typical for an aging human body focusing on the brain, cardiovascular and musculoskeletal systems. We will also discuss what it means to become older within a community, what can a person expect during the aging process, and what kind of control a person has over his/her aging body. Course participants travel to local aging centers and continuing care facilities as part of the learning process.

3030/6030§ Anatomy and Physiology for Engineers (3)
Dr. Dancisak
Prerequisite: either CELL 1010 or EBIO 1010
Co-requisite: BMEN 3035
Open only to BMEN majors.
This is a single-semester course in human structural anatomy. Course participants will examine both typical and pathological examples for the various subsystems including, body tissues; the musculoskeletal, neurological, cardiovascular, respiratory, digestive and reproductive systems.

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1 6xxx courses marked with § are open ONLY to graduate students. All other 6xxx courses are open to graduate students and also to advanced undergraduate students.
Anatomy and Physiology for Engineers Lab (1)
Dr. Dancisak
Co-requisite: BMEN 3030/6030
This single-semester laboratory coordinates hands-on learning in human structural anatomy. Course participants will dissect human cadavers and examine both typical and pathological examples for the various subsystems including, body tissues; the musculoskeletal, neurological, cardiovascular, respiratory, digestive and reproductive systems.

Quantitative Physiology (3)
Tulane University Health Sciences Center Staff
Prerequisite: CHEM 1070, CHEM 1080, CELL 1010, BMEN 2600. Co-requisite: BMEN 3075/6075
Open only to BMEN majors.
This course places emphasis upon the chemical basis of life; cells and cellular metabolism; histology and tissues; the endocrine, skeletal and nervous systems; respiratory, digestive, cardiovascular, lymphatic and reproductive systems; nutrition and metabolism; water, electrolyte and acid-base balance, and human growth and development.

Quantitative Physiology Lab (1)
Tulane University Health Sciences Center Staff
Co-requisite: BMEN 3070/6070
Subject matter will include blood, nutrition, and metabolism; and the cardiovascular, lymphatic, digestive, respiratory, urinary, and reproductive systems.

Biomaterials &Tissue Engineering (3)
Dr. Moore, Dr. Miller
Prerequisites: ENGP 3120 and BMEN 2600, or permission of instructor.
This course will focus on fundamental materials science and biological principles that impact the engineering design of biomaterials and tissue-engineered products. Topics addressed will include structural hierarchies of materials and tissues, physical and chemical properties of surfaces, degradation of materials, and cell-surface, cell-cell, and cell-matrix interactions. The course will conclude with inflammatory, immunological, and pathological events associated with responses to such products. Laboratory exercises will be utilized to illustrate selected concepts, introduce assessment methods, and provide hands-on experiences with cells and materials. Fulfills departmental “domain” requirement. An additional non-graded weekly lab section accompanies lectures.

Biofluid Mechanics (3)
Dr. Bull, Dr. Miller
Prerequisites: ENGP 1410, ENGP 2430, MATH 2240
This class focuses on fundamental concepts and properties of fluid mechanics with applications to the body. Topics to be covered include basic equations of fluid statics, dynamics and mass transport in differential and integral form using both system and control volume viewpoints. Rheological properties of biological fluids are studied as well as dimensional analysis and similarity. Advanced applications are investigated using the finite element method.

Biomechanics and Biotransport (3)
Dr. Bull
This course introduces students to biomechanics and biotransport. Specific topics include: the analysis of forces and stresses/strains in biological structures under loading; constitutive models for biological materials; the relationship between structure and function in tissues and organs. These topics will be related to fundamental principles of fluid mechanics and mass transport of biological systems at the cellular, tissue, and organ levels including cell adhesion and migration; intracellular, transmembrane and transvascular transport; drug transport and pharmacokinetics. Fulfills departmental “domain” requirement.

BMEN Seminar (0)
Each week, a one-hour seminar or current research is presented.

Biomedical Signals and Systems (3)
Dr. Brown
Topics include Laplace and Fourier transforms the convolution theorem, time- and space-frequency-domain analysis, signals and noise, the mathematics of imaging, and examples and applications to biomedical signals. The use of MATLAB and Simulink to analyze biomedical systems will be reinforced.

Mathematical Modeling and Analysis of Biological Systems (3)
Dr. Gaver; Dr. Wang
Prerequisite: MATH 2240, CELL 1010
The objective of this course is to teach basic mathematical modeling constructs and analysis techniques that are used for studying biological processes. Topics to be covered include ordinary differential equations, compartment systems, basics of dynamic systems, stability, statistical inference and model construction. These will be applied to study models of chemical kinetics, physiological control, AIDS transmission, population dynamics, and growth. Students will use Mathematica to develop and analyze models.

Elements of BMEN Design (3)
Dr. Anderson
Prerequisite:
ENGP 2430
This course develops the fundamental aspects of the mechanical performance of devices and components. Topics include a review of stress analysis, failure criteria, fatigue analysis and stress concentrations, as well as the mechanical behavior of fasteners, welded joints, spring selection, bearing design, and introduction to fi-
nite element analysis; with applications to biomedical engineering.

4030-4040 Team Design Projects I and II (2,3)
Dr. Gilbertson
Prerequisite: at least one 3xxx domain course from
Table 1
Techniques and experience in the solution of constrained and open-ended design problems. Lecture topics include all aspects of the design process, including goal setting, idea generation, prototyping, fabrication, and product and evaluation. Also included are technical presentation, project planning and management. Included as needed are other topics such as standards, fastening and joining, motors and control, esthetics and finish. Each team will design and construct a device or system to assist an individual with a disability. These designs are presented in a public show during the second semester.

4090-4100 Special Problems in Biomedical Engineering (1-4)
Staff
Independent study and investigation of special problems in biomedical engineering. Details to be arranged with individual biomedical engineering faculty members.

4890 Service Learning: Beyond Design (1)
Dr. Gilbertson
Prerequisite: Approval of instructor
Required co-requisite: BMEN 4030 or 4040
The required BMEN 4030/4040 design sequence is centered on the design and construction of a device or system to assist an individual with a disability or a group servicing such individuals. As an option, students may choose to supplement their interaction with their clients with a service learning component that follows Tulane’s guidelines for service learning courses and specifically requires: Completing at least 40 hours in a community setting during the semester; keeping a journal of weekly activities that will allow the student to describe and evaluate his/her experiences with the activity; and creating a product that can be evaluated as part of the course grade (e.g., a review paper on an issue relevant to the service activity, or some product of value to the site).

4900 RPP: Art of Professional Engineering (1)
Research and Professional Practice (RPP) is a 2-semester sequence beginning in Spring of the Junior year. It satisfies the University’s “Writing Intensive” requirement. A lecture series in the Spring semester, called “Art of Professional Engineering” includes economic analysis, ethics, professional communication including writing and oral presentation, research techniques including literature searching, citation, and the structure of a scientific paper.

Students must also register for either 4901 or 4902 in the Spring semester, and continue the sequence with 4911 or 4912 in the following Fall semester.

4901-4912 RPP: Grand Challenges I and II (2)
Dr. Anderson, Dr. Dancisak, Dr. Gilbertson
Pre-requisite: Instructor Approval. The 2 semester sequence presents a group of upper division undergraduates with a very difficult problem in biomedical engineering that will require creative invention, innovation, laboratory hard skills, and unique design methodologies to address. Though the problem is tractable, is not expected that the GC problem will be completely solved. Rather, the intent is that the GC group of students will push forward a developed “good solution” to the point where the need to protect intellectual property arises, and where market value and potential venture investment is apparent.
4902-4912 RPP: Senior Research and Profession Experience I and II (2)
This two-course sequence is designed to facilitate an individual biomedical research or design experience in a laboratory. Students will be introduced to the tools, techniques, and rules necessary to function independently and professionally as a researcher or engineer. Topics include thesis writing, technical communication, and time management. The main component of the course is a two semester long research or design project under the direction of a faculty member, scientist or other professional. The course sequence culminates in a formal Senior Thesis and Research Conference presentation. Students participating in the 5th year BSE-MS program should not register for BMEN4912 in the Fall of the Senior year, registering instead for BMEN 4930.

4930 Advanced Undergraduate Research (2)
Dr. Anderson
In order to meet undergraduate degree requirements, this course will allow fifth year students to more effectively concentrate on their research projects in lieu of completing the course requirements of BMEN 4912. The grade for BMEN 4930 will be listed as In Progress (IP) until the master's thesis is completed, whereupon the student's advisor and thesis committee will assign a grade necessary to fulfill bachelor's degree requirements.
Pre-requisites: Approval of instructor; admission to 5th year BSE-MS program

6170 Biomedical Optics (3)
Dr. Brown
The field of biophotonics is a rapidly-expanding research area in which the interactions of photons with matter are leveraged to increase our understanding of biology and to improve the outcomes in human medicine. The objectives of this course are to familiarize students with the fundamental interactions between light and biological samples, and how these are implemented in an array of technologies that are finding successful application in biomedical research and clinical application. Topics will include fundamentals of photon transport in turbid media; optical spectroscopy variants (reflectance, fluorescence, Raman; steady-state and time-resolved); diffuse optical imaging; biological microscopy; coherence techniques; hybrid technologies (e.g. photo-acoustic imaging); and optical molecular imaging. Special attention will be paid to quantitative methods for spectroscopy and imaging in solid tissues. The class will be composed of lectures, and interactive discussions on recent papers representing the state of the art in the field.

6220 Neural Microengineering (3)
Dr. Moore
This course will focus on microscale tools, technologies, and techniques employed for the control, manipulation, and study of the nervous system in vitro. Course material will be presented primarily by students who prepare presentations from extensive background literature review. A number of projects will be assigned as design challenges in which multiple groups will research and present proposed solutions to the same challenge.

6260 Molecular Principles of Functional Biomaterials (3)
Dr. Moore
Prerequisite: BMEN 3230/6230$
Functional biomaterials are non-viable materials that have been designed or modified in order to elicit specific biological responses when interacting with human fluids, cells, tissues, or organs. This course will focus on chemical principles utilized in endowing polymeric materials with biological functionality for medical applications. Following a brief review of polymer properties with a focus on hydrogels, topics addressed will include attachment of proteins to materials, induction of cell-binding and differentiation, responsive polymers, and spatial and temporal control of material properties for biological signaling. Unifying concepts will be introduced by directed reading and discussion of landmark papers in the biomaterials literature. Supplemental laboratory exercises will be utilized to illustrate selected concepts and introduce experimental procedures.

6310 Continuum Models in Biomedical Engineering (3)
Dr. Anderson
Prerequisites: ENGP 2430, BMEN 3440, BMEN 3300/6300$
The course begins with a presentation of the kinematics of continuous media and elementary tensor manipulations. We will then cover the conservation principles of mass, linear momentum, angular momentum, and energy. Additional topics will include the formulation of constitutive laws, continuum models in electrodynamics, and simple descriptions of piezoelectric materials. These concepts will be applied to fundamental problems in bio-solid mechanics, bio-fluid mechanics, and bio-electromagnetism.

6330 Advanced Biofluid Mechanics (3)
Dr. Gaver
Prerequisites: ENGP 2430, BMEN 3440
This course will cover general intermediate/advanced fluid mechanics, and will provide a foundation from which to base one's studies of biofluid mechanics. Issues pertinent to the study of biofluid mechanics will be emphasized. Topics to be studied include kinematic principles, the Navier-Stokes equations, boundary conditions for viscous flows, basic solutions to steady and unsteady Navier-Stokes equations, turbulence, analysis of the vorticity equation, and interfacial phenomena. Whenever possible, problems of a biological nature will be used as examples.
*6340 Soft Tissue Mechanics (3)
Dr. Miller
Prerequisite: ENGP 2430, BMEN 3300
This course provides an introduction to the various approaches used in modeling soft tissues, with particular attention paid to those of the cardiovascular, musculoskeletal and system (e.g. tendon). Particular emphasis will be placed on the theoretical and experimental con- sequences of the large deformation behavior of these tissues. An important objective of this class is to enable the student to develop a sense for the physical and mathematical relationships between the many types of models (and the associated experiments) currently being utilized in soft tissue mechanics.

6360 Introduction to Finite Element Analysis (3)
Staff
Prerequisite: BMEN 3300 or equivalent
Matrix structural analysis techniques as applied to frames, problems in plane strain, plane stress, and axisymmetric and 3-D structures. Development of the isoparametric family of finite elements. Use of user written and packaged software.

6430 Vascular Bioengineering (3)
Prerequisite: BMEN 3070, BMEN 3400/6400§
The objectives of this graduate-level course are to familiarize students with contemporary research areas that cover the field of vascular biology, and to provide an understanding of bioengineering principles related to physiological function and therapeutic modalities. Example topics include smooth muscle cell and endothelial cell lineage, leukocyte-endothelial cell interactions, angiogenesis, drug targeting via the microcirculation, neural vascular control, atherosclerosis, and hypertension. These topics will be presented in the context of four over-arching sections: 1) Vascular Cell Biology; 2) Principles of Vascular Function and Design; 3) Vascular Pathophysiology, and 4) Therapeutic Design. For each section of the course students will be required to read, critically analyze, and present relevant articles. As indicated by the section titles, the course will culminate by highlighting how our basic understanding of physiological function/dysfunction can be translated to therapeutic design.

*6460 Cellular Mechanotransduction (3)
Staff
Prerequisites: ENGP 2430, BMEN 3030, BMEN 3440/6440§ or instructor’s approval.
This course reviews cellular mechanotransduction in a variety of tissues that adapt to physiological loading. A partial list of mechanosensing cells sells in these tissues include hair cells in inner ears, chondrocytes in cartilage, osteocytes in bone, endothelial cells in blood vessels, etc. In particular, this course emphasizes the role of mathematical modeling in solving biological problems. Hands-on mathematical modeling will be assigned as homework and projects.

6600 Computational Modeling of Biomedical Systems (3)
Dr. Khismatullin
The objective of this graduate course is to provide students with the skills and knowledge necessary for computational modeling of biological and physiological systems. The first half of the course will cover introduction to UNIX, elements of programming (Matlab and FORTRAN), and numerical methods commonly used in biomedical research. The second half will immerse the students in specific biomedical applications including hemodynamics, respiratory flow, cellular mechanobiology, and neural dynamics. Most lectures will be accompanied by computer labs.

6610 Introduction to Computational Biomechanics (3)
Dr. Khismatullin
This course covers fundamentals of computational methods with the emphasis in biomechanics applications. The computational methods include finite element methods and finite difference methods at the introductory level. The course will use MATLAB to implement these methods. The underlying theories of these numerical methods will be taught, and example problems will be discussed during the lecture. Example problems will include those from implant design, bone biomechanics, soft tissue biomechanics, etc. in static and dynamic conditions. The course will also discuss some special issues such as the stability/convergence criteria and the error estimation. The student will work on a term project to exercise these issues on a biomechanics problem of his/her choice.

6630 Cell Mechanics (3)
Dr. Khismatullin
Fundamental principles of continuum mechanics will be applied to problems of biomechanics at the cellular level. Topics covered include structure of mammalian cells, cell membrane mechanics, mechanics of the cytoskeleton, models of cell viscoelasticity, cell adhesion, active cell processes, flow-induced deformation of blood cells, and experimental techniques (micropipette aspiration, biointerface probe, atomic force microscopy, magnetic twisting cytometry, optical tweezers, and flow chamber assays).

*6670 Pulmonary Mechanics (3)
Dr. Gaver
Prerequisite: MATH 2240, BMEN 6330 or equivalent
This is a survey course in which mechanical models of the pulmonary system are discussed. Topics to be addressed include mucous transport, airflow/diffusion in the pulmonary airways, ventilation/perfusion relationships, flow through collapsible airways and interfacial phenomena.
6680 Orthopaedic Bioengineering (3)
Dr. Gilbertson
Prerequisites: ENGP 1410, ENGP 2430, ENGP 3120 Concentration on various engineering aspects of the human knee and the treatment of its common orthopaedic pathologies. Topics include histophysiology of wound healing, synovial joint anatomy and tissue biomechanics, knee biomechanics, osteochondral and ligamentous graft reconstruction, prosthetic ligaments, and knee arthroplasty with emphasis on the design issues involved and the integration of clinical practice.

6710-6720 Seminar, Research Day Conference (1, 0)
Each week, a one-hour seminar on research within or outside the department is presented. During the Spring semester, all seniors are required to give a presentation on their project or internship. Attendance of all graduate students is required in the Fall semester.

6740 Data Acquisition and Control (3)
Prerequisite: BMEN 2730
Acquisition, digital processing, and output of signals of biomedical interest. Closed loop control applications for medical devices. Programming in the National Instruments LabVIEW environment. In-lab and final projects.

6790 Biomedical Engineering Design Studio (3)
Dr. Anderson
Prerequisites: BMEN Graduate or BMEN Senior Undergraduate standing.
This course is intended to provide students with a realistic design experience from virtual design, to rapid prototype fabrication, to testing, through redesign. It will focus on the practical application of leading commercial design software, including the creative extension of this software to innovate research applications. The course will be project intensive with commensurate report submissions and future design recommendations. Projects will include analyses of existing clinical problems, as well as research development of cell scaffolds and cell mechanotransduction.

6830 Intro to Biomedical Imaging & Image processing (3)
Dr. Yu-Ping Wang
Prerequisites: Experience with MATLAB
The objective of this course is to teach graduate students the concepts, algorithms and programming of image analysis techniques and apply them to address real world biomedical imaging challenges. The physics of medical imaging modalities including x-ray, MRI, CT, PET and microscopic imaging will be introduced. The basic underlying mathematical signal processing techniques such as Fourier analysis and linear system theory will be studied to model and process biomedical images. Finally, students will learn how to use MATLAB as a tool and apply the image processing techniques to solve some medical imaging problems such as image enhancement, segmentation and pattern classification.

BMEN 6840 Medical Imaging Physics (3)
Dr. Bayer
Prerequisites: BMEN3730/BMEN6730 Biomedical Signals and Systems or equivalent
This course will introduce imaging methods in medicine, including radiography, computed tomography (CT), magnetic resonance imaging (MRI), nuclear medicine (PET and SPECT), and ultrasound imaging. The basic physical principles of each imaging modality will be introduced, including the imaging energy source, properties and interaction with tissue. Basic concepts of image reconstruction will be discussed. This course will include laboratory visits to the School of Medicine Department of Radiology to explore real world uses of medical imaging systems. A course project will be assigned for students to assess new and emerging medical imaging systems.

6930 TRIZ-Theory of Inventive Design (3)
Dr. Gilbertson
The objective of this course is to introduce students to TRIZ (Russian acronym for “Theory of Inventive Problem Solving”—a design method initially developed in the Soviet Union and used today by many Fortune 500 companies. TRIZ is an algorithmic approach to solving technical problems. In this course, students will learn and apply TRIZ principles to the design of technical systems in their area of interest—including but not limited to medical implant design, scientific research, and assistive device technology. 3910 fulfills departmental “domain” requirement; 6930 additionally requires patent search and application of TRIZ to “design around a patent”.

7100 Current Topics in Biomedical Engineering (3)
This course focuses on state-of-the art technologies and scientific discoveries in biomedical engineering. Experimental design/analysis topics will include proper controls, statistics, data presentation, and data interpretation. These types of technologies to be included are in the areas of epigenetics and genetics, molecular and cellular biology, proteins, mechanics and materials science, modeling and simulation, high-throughput omics, and/or imaging. Seminal articles from top-tier journals in the field of biomedical engineering will also be selected and discussed in class. The chosen articles will span a wide range of topic areas including articles that focus on basic science as well as fundamental engineering. Student-based discussion is a key component of the teaching approach utilized.

7210-7220 Directed Readings in Biomedical Engineering (1-6)
Taught on a tutorial basis, this course allows a student to make an in-depth study in an area of expertise of members of the department. Some recent and current topics include non-Newtonian fluid mechanics; the mechanics of the inner ear; the mechanics of bone; the mechanics of soft tissue; ceramics engineering; physical metallurgy; laser applications in medicine; and
modeling of neural networks.

*7410 Research Methods (3)  
Staff  
Methods and resources for experimental studies in engineering science are introduced. Topics include the nature of scientific inquiry, literature search and writing techniques, experimental design and control, data analysis and presentation, and statistical methods. An original proposal is required.
Full-Time Faculty

Nicholas J. Altiero, Professor Ph.D., University of Michigan, 1974 Research interests: Computational mechanics, fracture mechanics and biomechanics.

Ronald C. Anderson, Associate Professor; Ph.D., Tulane University, 1987. Research interests: Biomechanics, orthopedic materials.

Carolyn Bayer, Assistant Professor; Ph.D. University of Texas at Austin Research interests: Ultrasound, Photoacoustic imaging and imaging contrast agents.

J. Quincy Brown, Assistant Professor; Ph.D., Louisiana Tech University, 2005. Research interests: optical spectroscopy and imaging, biophotonics, image-guided surgery, optics in oncology, biosensors, technology translation

Joseph Bull, Professor, John and Elise Martinez Biomedical Engineering Chair; Ph.D., Northwestern University, 2000. Research Interests: biofluid mechanics, ultrasound, theoretical and computational modeling.

Michael Dancisak, Senior Professor of the Practice and Director of the Center for Anatomical and Movement Science; Ph.D., University of Minnesota, 2000. Research Interests: performance enhancement for individuals working in healthcare & performing arts.

Donald P. Gaver, Alden J. 'Doc' Laborde Professor and Department Chair.; Ph.D., Northwestern University, 1988. Research interests: Biofluid mechanics, pulmonary mechanics, bioremediation, biocomputing.

Lars G. Gilbertson, Senior Professor of the Practice and Director of Undergraduate Studies; Ph.D., University of Iowa, 1993. Research interests: Biomechanics, robotics-assisted measurement of in-vitro kinetics, neuromuscular control of spinal movement.

Damir Khismatullin, Associate Professor; Ph.D., Bashkir State University, 1998. Research interests: Modeling the mechanical behavior of biological systems at cellular and tissue levels, biomechanics.

Kristin S. Miller: Assistant Professor; Ph.D., University of Pennsylvania, 2012. Research Interests: Continuum biomechanics, growth & remodeling, mechanobiology, orthopaedics, women’s reproductive health.

Michael J. Moore, Associate Professor; Director of Graduate Studies; Ph.D., Mayo Clinic College of Medicine, 2005. Research interests: Tissue engineering, biomaterials, central nervous system regeneration.

Katherine K. Raymond, Professor of the Practice; Ph.D., Tulane University, 2007. Research interests: Mechanics, Engineering Materials

Yu-Ping Wang, Professor; Ph.D., Xi’an Jiaotong University, P. R. China, 1996. Research interests: Medical imaging, bioinformatics, genomic signal processing and systems biology.

Eiichiro Yamaguchi, Assistant Research Professor, Ph.D., University of Illinois at Urbana, 2005 Research Interests: Development of optical diagnostics methods, such as Particle Image Velocimetry (PIV) and Laser Induced Fluorescence (LIF), for microscale flow systems. Study of micro-fabrication techniques.
**Emeritus Faculty**

**Paul L. Nunez**, Professor Emeritus; Ph.D., University of California at San Diego, 1969. Research interests: Electroencephalography, signal processing, neocortical dynamics.

**David A. Rice P.E.**, Professor Emeritus; Ph.D., Purdue University, 1974. Research interests: Physiologic modeling, cardiopulmonary mechanics, bioacoustics, instru-mentation and signal processing.

**San Aung**, Professor of the Practice, SSE; Ph.D., Tulane University, 2000.

**William C. Van Buskirk P.E.**, Professor and Chair Emeritus of Biomedical Engineering, Dean Emeritus of Engineering; Ph.D., Stanford University, 1970.


**Affiliated Faculty**

**Ming Li**, Associate Professor, Department of Physiology; Ph.D. University of Iowa, 1989.

**Adjunct Faculty**

**Taby Ahsan**, Director, Analytical Development, Rooster Bio Inc; Ph.D., University of California, San Diego. 1998 Research Interests: Tissue engineering, stem cell research, Appointment through 06/30/21


**James T. Bennett**, Professor, Professor of Orthopaedics, Clinical Professor of Pediatrics, Tulane University; M.D., Tulane University, 1978. Spine Mechanics. Appointment through 06/30/21

**Darren Cheng**

Department of Biomedical Engineering, Tulane University; M.S., Tulane University, 2015. Appointment through 06/30/21

**Douglas B. Chrisey**, Jung Professor of Engineering Physics, Tulane University; Ph.D., University of Virginia, 1988. Materials Engineering. Appointment through 06/30/21

**Lowry Curley**, CEO of AxoSim Technologies Ph.D., Tulane University, 2012. Appointment through 06/30/21

**Hong-Wen Deng**, Department of Biostatistics, School of Public Health and Tropical Medicine, Tulane University; Ph.D., University of Oregon, 1995. Appointment through 06/30/21

**Sherif Ebrahim Ph.D.**, Freeman School of Business, Tulane University, Professor, Strategy & Innovation and Director of Entrepreneurship and Innovation Education. Appointment through 06/30/21

**David Halpern**, Professor, Department of Mathematics, University of Alabama, Tuscaloosa; Ph.D., University of Arizona, 1989. Biofluid Mechanics, Computational Fluid Dynamics, Applied Mathematics. Appointment through 06/30/21

**Pleasant Fite Hooper, MD**: Founder & Owner, TMS BioScience Labs, M.D. University of Mississippi Medical Center, 1984. Appointment through 06/30/21

**Anne-Marie Job**, Director of Research Proposal Development, Office of Research, Tulane University, Ph.D., Tulane University, 2011. Appointment through 06/30/21


**Jian Li**, Department of Biostatistics, School of Public Health and Tropical Medicine, Tulane University; Ph.D., North Carolina State University, 2005. Appointment through 06/30/21

**Walter Lee Murfee III**, Associate Professor; Ph.D., University of Virginia, 2005. Research interests: Microvascular biology, cell-tissue engineering. Appointment through 06/30/21

*Note: Adjunct appointments are generally made for three-year terms*
Appendix C. Undergraduate projects
Undergraduate Team Design Projects 2015-2016

BME Senior Team Design Projects 2017-2018

10donFix
Clara Ives, Monica Kala, Matthew Nice, Dinika Singh, David Watson

adJUST the Tip
Lauren Hymel, Sean LeBoeuf, Rebecca Levy, Avery Newsom

AMBLE
Hayden Lane, Kristine Spicer

Channel TU
Isadora Decker-Lucke, Adam Kolkin, Laura Krasovec, Jeong min Oh, Joshua Yao

Colonoloop
Daniel Bolus, Bridget Daugherty, Adrian Jones, Jaclyn Sider

Team InnoFemme
Andrew Begeman, Karissa Chao, Caroline Swan

Team InnoVentri
Alex Clarke, Andrea Green

ScoliTech
Theodore Airey, Andrew Markel, John McGee, John F, Julia Weinstock

Team SignalMe
Megan Escott, JJ Libler, Taylor Sabol

Straight Up Posture
Ryan Barr, Zach Harris, Sarah Holt

Tendon Love and Care
Carly Askinas, Emma Bortz, Erika Chelales, Madison Vanosdoll

TU Wheelies
Laquel Brown, Dana Kaplan, Catherine Starks
GRAND CHALLENGES 2017 TOTAL KNEE ARTHROPLASTY SURGERY SYSTEM
Andrew Begeman, Alexandra Clarke, Mohammed Elaasar, Sarah Holt, Theodore Airey
John F. McGee, Sean LeBoeuf, Andrea Green, Jeffrey Libler, Avery Newsom
James Hayden, Julia Weinstock, David Watson Laquel Brown, Zachary Harris, Kristine Spicer

PARAMETER CHARACTERIZATION FOR MAGNETIC FLUID HYPERTHERMIA THROUGH INDUCTION HEATING
Karissa Chao, Benjamin Vinson, Douglas Chrisey, Ph.D.

SINGLE CELL ANALYSIS OF THE PHYSICAL MICROENVIRONMENT TOWARDS UNDERSTANDING STEM CELL HETEROGENEITY
Clara J Ives, Brendon Baker

THE EFFECT OF VASCULAR ENDOTHELIAL GROWTH FACTOR ON CAPILLARY SPROUTING IN THE MOUSE MESOMETRIUM TISSUE CULTURE MODEL
Dana R. Kaplan, Ariana Suarez-Martinez, Walter Lee Murfee, Ph.D.

COMMERCIALIZATION EXTERNSHIP AT THE NEW ORLEANS BIOINNOVATION CENTER
Bridget K. Daugherty

DEVELOPMENT OF ANALYTICAL TOOLS FOR THE ASSESSMENT OF ACOUSTIC TWEEZING THROMBOELASTOMETRY
Erika M. Chelales, Daishen Luo, Nithya Kasireddy, Damir B. Khismatullin, Ph.D.

SYNERGISTIC ENHANCEMENT OF LIPOSOMAL CHEMOTHERAPY BY HIGH INTENSITY FOCUSED ULTRASOUND FOR PROSTATE CANCER TREATMENT IN VIVO
Monica D. Kala, Damir Khismatullin, Ph.D.

IMPACT AND ANALYSIS OF THE POINTE SHOE ON BALLET DANCERS
Dinika Singh, Michael J. Dancisak, Ph.D.

HIGH-INTENSITY FOCUSED ULTRASOUND IS SYNERGISTIC WITH ETHANOL IN REDUCTION OF LIVER CANCER PROGRESSION IN VITRO
Emma P. Bortz, Hakm Y. Murad, Damir B. Khismatullin, Ph.D.

ULTRASOUND-ENHANCED THERAPY FOR AXON NEUROGENESIS
Adrian M. Jones, Asis Lopez, Daishen Luo, Damir B. Khismatullin, Ph.D.

PRESSURE-CONTROLLED FORMALIN FIXATION DEVICE FOR IMPROVED HISTOLOGICAL CHARACTERIZATION OF THE FEMALE REPRODUCTIVE TRACT
Catherine C. Starks

A COMPUTATIONAL MODEL SIMULATING AN AIRWAY WITH VARIED LIQUID LINING AND PARENCHYMAL TETHERING
Laura C. Krasovec, Jason Ryans, Dr. Hideki Fujioka, Donald P. Gaver, Ph.D.

CONSTRAINING NEURITE OUTGROWTH FOR INCREASED REPRODUCIBILITY IN NERVE-ON-A-CHIP CONSTRUCTS
Rebecca A. Levy, Devon A. Bowser, Michael J. Moore, Ph.D.
ANALYSIS OF SURFACTANT-MEDIATED CELL MEMBRANE WOUND REPAIR DURING PULSATILE FLOW IN A BIOMIMETIC AIRWAY USING ELECTRIC CELL-SUBSTRATE IMPEDANCE SENSING
Joshua E. Yao, Donald P. Gaver, Ph.D.

DEVELOPMENT OF AN AGENT-BASED MODEL TO PREDICT SALIENT FEATURES OF AGE-RELATED TENDON DEGENERATION
Madison K. Vanosdoll, Mary Mulcahey, Kristin S. Miller, Ph.D.

INDUCTION OF ANGIOGENESIS IN THE MOUSE MESENTERY
Matthew W. Nice, Ariana D. Suarez-Martinez, Walter L. Murfee, Ph.D.

QUANTITATIVE ANALYSIS OF VESSEL-ALIGNED NERVES IN RAT MESENTERIC TISSUE CULTURES
Ryan W. Barr, Nicholas A. Hodges, Walter L. Murfee Ph.D.,

DEVELOPMENT OF AN AGENT-BASED MODEL AND A MECHANICAL TESTING PROTOCOL TO PREDICT AND MEASURE THE FACTORS AFFECTING VAGINAL WOUND HEALING
Taylor Sabol, Jason Schuster, Kristin S. Miller, Ph.D.

PHOTOACOUSTIC IMAGING TO MEASURE PLACENTAL RESPONSE TO INDUCED HYPOXIA
Megan E. Escott, Dylan J. Lawrence, Carolyn L. Bayer, Ph.D.

Optimizing Light Delivery for Photoacoustic Imaging Using Monte Carlo Simulations
Adam D. Kolkin, Carolyn L. Bayer, Ph.D.

REPURPOSING A FLUORESCENT PROBE AS A PHOTOACOUSTIC CONTRAST AGENT TO POTENTIALLY DETECT REACTIVE OXYGEN SPECIES IN VIVO
Andrew Markel, Wu Chengxi, Bernard Ogola, Sarah Lindsey, Carolyn Bayer, Ph.D.

VALIDATION OF A WIRELESS OPTOGENETIC STIMULATION SYSTEM
Lauren Hymel, Zachary Murdock, Andrew Davidson, Ricardo Mostany, J. Quincy Brown, Ph.D.

A STUDY OF CYTRAK ORANGE AS A SINGLE STAIN H&E ANALOG, AND ANTIBIOTICS AS IN VIVO FLUORESCENT IMAGING AGENTS
Isadora E. Decker-Lucke, Kate Elfer, J. Quincy Brown, Ph.D.

OPTIMIZATION AND VALIDATION OF BODIPY FOR QUANTIFICATION OF STEATOSIS IN DONOR TRANSPLANT LIVERS
Carly Askinas, Kate Elfer, David Tulman, J. Quincy Brown, Ph.D.

PROCESSING OF SELECTIVE PLANE ILLUMINATION MICROSCOPY IMAGES TO GENERATE LARGE, WORKABLE 3D TISSUE VOLUMES
Daniel J. Bolus, Bihe Hu, J. Quincy Brown, Ph.D.

THE USE OF SELECTIVE PLANE ILLUMINATION MICROSCOPY IN IMAGING A PN1A MOUSE MAMMARY GLAND MODEL WITH DUCTAL CARCINOMA IN SITU
Caroline G. Swan, J. Quincy Brown, Ph.D.
CONSTRUCTION OF “NERVE-ON-A-CHIP” USING MAGNETIC 3D BIOPRINTED SPHEROIDS: A FEASIBILITY STUDY
Jeong min Oh, Michael J. Moore, Ph.D.

EVALUATION OF A PROTOTYPE OF THE TABLETOP 3D PHOTOACOUSTIC/FLUORESCENCE IMAGING PLATFORM FOR BIOMEDICAL RESEARCH
Jaclyn G. Sider, Chengxi Wu, Carolyn Bayer, Ph.D.
## Graduate Degrees, 2009-201

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<td>2016</td>
<td>MS</td>
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<td>A Platform for Rapid Electrophysiological Examination of Hydrogel Neurite Constructs</td>
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<td>Longitudinal Tracking of Pulmonary Epithelial Cell Injury and Detachment during Sequential Recruitment and Derecruitment in a Model of Atelecuma</td>
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<td>How Does Airway Flexibility Impact the Biological Response to Pulmonary reopening?</td>
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<td>Kevin Chiu</td>
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<td>Michael J. Moore, Chair</td>
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<td>Production and Characterization of Biological Nanoparticles for the Development of a Novel Vaccine against Methicillin-resistant Staphylococcus aureus</td>
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