

RESOLUTION TO APPROVE BACHELOR OF SCIENCE DEGREE IN BIOMEDICAL ENGINEERING

Documents included:

1. Resolution to Establish Bachelor of Science Degree in Biomedical Engineering
2. Supporting Documentation- Bachelor of Science Degree in Biomedical Engineering
3. Presentation – slides

RESOLUTION TO ESTABLISH A BACHELOR OF SCIENCE DEGREE IN BIOMEDICAL ENGINEERING

WHEREAS, biomedical engineering is a rapidly emerging field that draws on engineering principles to provide training to undergraduate students so that they may tackle emerging societal issues related to engineering aspects of the growing field of health care; and

WHEREAS, graduates with a degree in biomedical engineering will analyze and design solutions to problems in biology and medicine with the goal of improving the quality of patient care through jobs at universities, hospitals, manufacturers, government agencies, and research facilities; and

WHEREAS, Virginia Tech is uniquely suited for such a degree program due to its established partnerships unavailable to other universities in Virginia or in the United States, including ties with prestigious groups such as the Edward Via College of Osteopathic Medicine, Virginia-Maryland College of Veterinary Medicine, Virginia Tech Transportation Institute, Institute for Critical Technology and Applied Science, Virginia Tech Carilion School of Medicine, Virginia Tech Carilion Research Institute and the Wake Forest School of Medicine; and

WHEREAS, the addition of a degree in biomedical engineering aligns with President Sands' goal that the university should strive to increase Virginia Tech's US rankings, become a top-100 global research university and continue to attract high-quality students with world-leading interdisciplinary programs and research opportunities. The College of Engineering is the only program in the top 50 across the U.S. without a biomedical engineering undergraduate program; and

WHEREAS, the biomedical engineering degree meets goals set in the Virginia Tech 2012-2018 Strategic Plan that proposes major growth in the fields of "science, technology, engineering, mathematics, and health sciences (STEM-H)". This degree will help Virginia Tech grow as a high-ranking institution and make its graduating students and alumni highly attractive to employers in the Commonwealth and beyond;

THEREFORE, BE IT RESOLVED, that the Bachelor of Science Degree in Biomedical Engineering be established, effective Fall 2017.

RECOMMENDATION:

That the above resolution recommending the establishment of the Bachelor of Science Degree in Biomedical Engineering be approved.

April 3, 2017

Virginia Tech Degree Proposal
Biomedical Engineering Bachelor of Science Degree
CIP: 14.0501

Type of degree action (circle one): New Spinoff Revision Discontinuance

Program Description

Virginia Polytechnic Institute and State University requests approval for the following degree: Bachelor of Science (B.S.) in Biomedical Engineering (BME). This degree will be offered by the Department of Biomedical Engineering and Mechanics (BEAM) in the College of Engineering (COE) at Virginia Tech and implemented in the fall of 2017. The purpose of this BME degree is to provide state-of-the-art academic training to undergraduate students so that they may tackle emerging societal issues related to engineering aspects of the growing field of health care. The new Bachelor of Science in Biomedical Engineering degree addresses anticipation of the US Department of Labor Statistics¹ for a 27% job growth from 2012-2022. This is more than double the 11% outlook for all occupations. Ten year data from the American Society of Engineering Education² (2002-2011) showed that even though the discipline is newer as compared to other engineering areas, the large interest in BME has allowed it to maintain a sizable growth rate in comparison to the other engineering fields in both undergraduate and graduate programs. Finally, biomedical engineering programs represent the largest growth in new engineering programs accredited by the Accreditation Board for Engineering and Technology (ABET)³ in recent years. The BME program will provide a new and exciting degree opportunity for undergraduates. Graduates from this degree program will have the critical thinking skills and laboratory competencies necessary to become leaders capable of addressing career opportunities that include, but are not limited to:

Design of Medical Devices: As the aging baby-boom generation lives longer and stays active, there is a pressing need to design systems and products that interact with and replace body parts. Novel technologies are needed to diagnose and treat medical problems more accurately than at present.

Optimize and Train on Biomedical Equipment: Providing technical assistance and training to clinicians as to the safety, efficiency, effectiveness and proper use of biomedical equipment will be a significant commitment as the health care industry expands with the aging population.

¹ Occupational Outlook Handbook. (n.d.). Retrieved from <http://www.bls.gov/ooh/architecture-and-engineering/biomedical-engineers.htm>

² Yoder, B. L. (2012). Engineering by the Numbers. *American Society for Engineering Education, Washington, DC*. Retrieved from http://www.asee.org/papers-and-publications/publications/14_11-47.pdf

³ Criteria for Accrediting Engineering Programs, 2015 – 2016. (n.d.). Retrieved from <http://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2015-2016/>

Pharmaceutical and Medicine Manufacturing: The demand for personalized health care will require advancement in medical therapeutics such as nanomedicine and drug delivery systems capable of targeting specific diseases.

Translational Scientific Research: Rapid advancement in technology will continue to create opportunities for biomedical engineers. Further translational research is needed to understand the engineering aspects of biological systems of humans and animals in order to advance prevention of injury and disease.

As evidenced by these select examples, the importance of training in biomedical engineering is reflected directly by a worldwide increase of health care needs. With the goal of designing solutions to problems in biology and medicine, biomedical engineers will have the opportunity to improve the quality and effectiveness of patient care. Due to the multidisciplinary nature of the biomedical engineering community, graduates with a degree in biomedical engineering are recruited into a broad range of health, industrial and educational activities. Individuals with a Bachelor of Science degree in Biomedical Engineering will be prepared to enter the job markets associated with these issues. Moreover, graduates with a Bachelor of Science degree in Biomedical Engineering will be prepared and competitive for entry into professional and graduate schools.

Based on these motivating factors and the department's unique capabilities, this program strives to **develop Biomedical Engineering and Mechanics (BEAM) as a national leader** in biomedical engineering undergraduate education. This will be accomplished by the following three objectives:

- **Educate and train the future biomedical engineers** for a complex, diverse and global workplace. The department will provide a high quality, relevant educational program using the latest technology and educational techniques.
- **Expose students and allow opportunities for students to conduct state-of-the-art research** that embraces societal challenges.
- **Capitalize on the department's biomedical partnerships** with: Virginia Tech Carilion and Virginia Tech Carilion Research Institute, Institute for Critical Technology and Sciences, Virginia-Maryland College of Veterinary Medicine, Biocomplexity Institute of Virginia Tech, Virginia Tech Transportation Institute, and Edward Via College of Osteopathic Medicine.

Curriculum Summary

A total of 122 credit hours will be required for the Biomedical Engineering degree. The Biomedical Engineering curriculum will include all requirements for the curriculum for General Engineering (29 credits) which include: Foundations of Engineering I and II (4), First-Year Writing I and II (6), Calculus of a single Variable I and II (8), General Chemistry and Lab (4), Foundations of Physics I with lab (first portion) (4), and 6 additional credits of Curriculum for Liberal Education (CLE)⁴ courses in areas 2, 3, 4 or in the Pathways Curriculum if that is adopted by the time of the major's estimated start date.

⁴ College of Engineering First Year Courses. Retrieved from:
<http://www.engr.vt.edu/undergraduate/courses.html>

Additional entry-level math and engineering courses will be required (21 credits). These should include Multivariable Calculus (3), Statics (3), Dynamics (3), Introduction to Differential Equations (3), Mechanics of Deformable Bodies (3), Introduction to Linear Algebra (3), and Statistics (3).

Additional entry-level science courses will also be required (19 credits). These should include Introduction to Biomedical Engineering (3), Foundation of Physics I with Lab (2nd portion) (4), Principles of Biology (3), Electrical Theory (3), Elements of Materials Engineering (3), and a programming course (3).

Collectively the 1000 and 2000-level courses will provide the necessary background that students will need in order to be successful their junior and senior year with the 3000 and higher courses. After successful completion of these courses with a grade of C- or higher, students should have a broad appreciation and understanding for the biomedical engineering field as well as the foundation for the Biomedical Engineering courses. The required coursework is designed to give students advanced critical thinking skills and exposure and practice related to research problems, laboratory and writing skills, and professional development.

In their junior and senior years, students will be required to take upper level BME classes (16 credits) which include BME Cellular Lab and Design (2); Fluid Mechanics I (3); Introduction to Medical Physiology (3); Bioinstrumentation and Design for Living Systems (2); Problem Solving in Biomedical Engineering (3); and Global Societal and Ethics in Biomedical Engineering (3). Additionally, they will be required to take 21 credits of special technical electives in the field and 10 credits in the Curriculum for Liberal Education (CLE) requirements (areas 2, 3, 6, and 7). *Note: The proposed Pathways Requirements will replace the Curriculum for Liberal Education should it be adopted by the start of this proposed degree.* Finally, students must complete 6 capstone senior design project credits in order to be awarded the Biomedical Engineering Degree.

The degree core for the Bachelor of Science in Biomedical Engineering (22 credits) will include Introduction to Biomedical Engineering (3); BME Cellular Lab and Design (2); Introduction to Medical Physiology (3); Bioinstrumentation Laboratory & Design (2); Problem Solving in BME (3); 6 credits of BME Senior Design and Project (6); and Global, Societal and Ethics in BME (3).

Working with their academic advisors, students will be able to customize their degree program to focus on sub-discipline areas within the broader field of biomedical engineering and prepare them for specific career objectives as well as graduate school. A capstone project in senior year along with the previous coursework will prepare students for networking with companies and provide a unique skillset and practice to enhance marketability after graduation. All of these requirements build upon the current BME minor which requires 6 credits of BME introductory course work, 6 credits of BME electives and 6 credits of BME research in addition to the College of Engineering and Virginia Tech course prerequisites. (See Appendix A)

Relevance to University Mission and Strategic Planning

The Virginia Tech Mission Statement⁵ states, "Virginia Tech is a public land-grant university serving the Commonwealth of Virginia, the nation, and the world community. The discovery and dissemination of new knowledge are central to its mission. Through its focus on teaching and learning, research and discovery, and outreach and engagement, the university creates, conveys, and applies knowledge to expand personal growth and opportunity, advance social and community development, foster economic competitiveness, and improve the quality of life." The proposed B.S. in Biomedical Engineering degree supports the instructional mission of the Department of Biomedical Engineering and Mechanics by creating a signature educational experience at Virginia Tech.

The Virginia Tech 2012-2018 Strategic Plan⁶ proposes major growth in the fields of "science, technology, engineering, mathematics, and health sciences (STEM-H)". Three principle strategies for improving undergraduate education are "Increase ... experiential learning opportunities by adopting a hands-on, minds-on philosophy that promotes connecting real-life experience with academic concepts, ...develop ways to integrate computational science / informatics and digital fluency for managing and analyzing complex data sets," and "Increase the quality and availability of academic advising for all students from orientation through graduation." A Bachelor of Science in Biomedical Engineering degree will provide students with the necessary tools to help Virginia Tech grow as a high-ranking institution and make its graduating students and alumni highly attractive to employers in the Commonwealth and beyond.

President Sands noted⁷ that the university should strive to increase Virginia Tech's US rankings, become a top-100 global research university and continue to attract high-quality students with world-leading interdisciplinary programs and research opportunities. A new Biomedical Engineering degree can help achieve these goals. A Biomedical Engineering degree would allow students to pursue a superior education that focuses on multidisciplinary research and global discovery. Analyses of research and economic projections clearly indicate that Biomedical Engineering is a leading growth area world-wide. In addition, implementing a degree in Biomedical Engineering will help recruit, educate, and graduate a talented and diverse undergraduate student body, which is a university priority. The Department of Biomedical Engineering and Mechanics expects that students graduating from Virginia Tech with a Biomedical Engineering degree will serve as key members of research, development, and manufacturing teams and translate ideas that grow from basic biomedical and clinical sciences into systems, devices, and techniques that can be patented, produced, and marketed to improve health care outcomes.

Justification for the Proposed Program

⁵ Mission and Vision Statements of the University. Virginia Tech. Retrieved from http://www.president.vt.edu/mission_vision/mission.html

⁶ 2012 Strategic Plan, A Plan For A New Horizon: Envisioning Virginia Tech. Retrieved from: <https://www.president.vt.edu/strategic-plan/strategic-plan.html>

⁷ Sands, T. (2014, October 17). Installation Speech by Timothy Sands. Retrieved from: <http://www.president.vt.edu/about-the-office/statements/101714-installation-speech.html>

⁸ <http://www.bls.gov/careeroutlook/2012/spring/spring2012ooc.pdf>

Biomedical engineering has become one of the fastest growing fields of engineering worldwide. The Bureau of Labor Statistics states that employment of biomedical engineers is expected to grow by 62 % from 2010 to 2020, much quicker than the average for all engineering professions⁸. At Virginia Tech, many undergraduate students are interested in BME, as evidenced by the number of students who are enrolled in the BME Minor Program (170 students as of January 2016). Currently, VT undergraduates who are interested in BME are advised to pursue a major in chemical, biological systems, or mechanical engineering, taking technical electives in the BME area. However, a dedicated undergraduate program will allow this opportunity to be marketed to bring additional opportunities within the College of Engineering.

Although gender diversity is poor in engineering as a whole, the BME discipline has historically been attractive to women. The fraction are those receiving BS degrees in BME who are women is approximately 40%. BME is a challenging program – integrating engineering and the biomedical sciences. Admission to the Virginia Tech BME program will be competitive. It is anticipated that such a program will attract many outstanding students, yet, the addition of a new undergraduate program in Biomedical Engineering at VT needs to be developed and implemented so that students within the program receive the same outstanding education as their fellow COE peers.

Virginia Tech is in a premier position to offer this new degree. A recent survey by Gallup indicated that “Virginia Tech alumni are more likely than the national college graduate comparison group as well as graduates in peer institution and research university cohorts to be thriving in every element of well-being.” Gallup defines the five elements as purpose, social, financial, community, and physical well-being.⁹ An undergraduate degree in Biomedical Engineering will help the Department’s future alumni achieve well-being in these five domains, increase Virginia Tech’s prestige, and invite more alumni donations as the Department’s students graduate with the ability to gain BME-related jobs.

Since the Department of Biomedical Engineering merged with the Department of Engineering Science and Mechanics, the new Department of Biomedical Engineering and Mechanics (BEAM) has seen tremendous growth both inside and outside of the department. This Department has unique partnerships unavailable to other universities in Virginia or in the United States, including ties with prestigious groups such as the Edward Via College of Osteopathic Medicine, Virginia-Maryland College of Veterinary Medicine, Virginia Tech Transportation Institute (VTTI), Institute for Critical Technology and Applied Science (ICTAS), Virginia Tech Carilion School of Medicine (VTCOM), and Virginia Tech Carilion Research Institute (VTCRI). The existing Biomedical Engineering graduate degree program and Biomedical Engineering undergraduate minor have already benefited from these unique partnerships and it is expected that a new undergraduate BME degree program will likewise benefit.

⁹ “Great Jobs, great lives: Virginia Tech alumni thrive, according to Gallup survey.” Virginia Tech. Web. 28 Aug. 2015. Retrieved from: <http://www.vtnews.vt.edu/articles/2015/08/082815-dsa-gallupalum.html>

Students in this program will have access to world renowned researchers in specialized fields of biomechanics, tissue engineering, neuroengineering, biomedical imaging, translational cancer research, cardiovascular engineering, nanomedicine, and nanobioengineering. The department's teaching and research expertise position it for a smooth transition from the BME minor to the B.S. in BME. Some of Virginia Tech's most prestigious faculty are affiliated with the Department of Biomedical Engineering and Mechanics including the Dean and University Center Directors.

Both faculty and student interest has steadily increased within the existing minor and graduate degree programs. By creating an undergraduate Biomedical Engineering degree, students will have the opportunity to study biomedical engineering fields intensively as well as double-major in BME and a wide variety of related degree programs such as Physics and other Engineering disciplines. This program will also prepare undergraduate students who want to pursue a graduate education in biomedical engineering, medicine, or other areas of science and engineering. As one of the top institutions in the United States, Virginia Tech's hands-on, engaged approach to education and preparation of scholars to be leaders in their fields and communities is an excellent foundation for a B.S. in Biomedical Engineering, a field that reflects the Virginia Tech motto *Ut Prosim* (That I May Serve).

Student Demand

There is tremendous student interest in the field of biomedical engineering at Virginia Tech. Because of expressed interest, a Biomedical Engineering minor was created in 2012. Enrollment in the minor has grown steadily and currently has 170 students enrolled. The student interest in biomedical engineering at Virginia Tech reflects the national trend showing strong interest among undergraduate students in biomedical engineering. As shown in Figure 1, data from the American Society for Engineering Education (ASEE)¹⁰, reveal that biomedical engineering is the 8th top major for undergraduate students in engineering colleges.

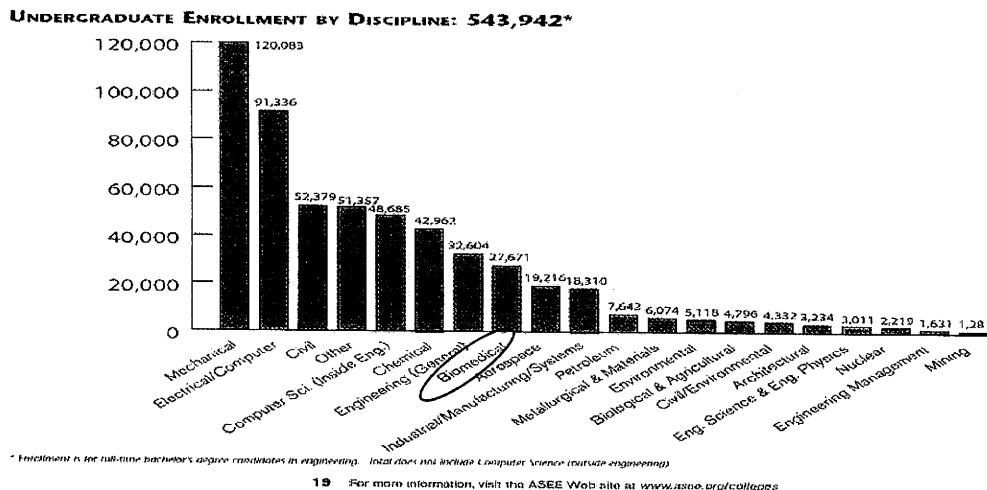


Figure 1. Undergraduate Enrollment by Discipline (2012-2013)¹⁰

¹⁰ Yoder, B. L. (2012). Engineering by the Numbers. *American Society for Engineering Education, Washington, DC.* http://www.asee.org/papers-and-publications/publications/14_11-47.pdf.

PERCENTAGE OF BACHELOR'S DEGREES AWARDED TO WOMEN BY DISCIPLINE: 19.1% OF TOTAL

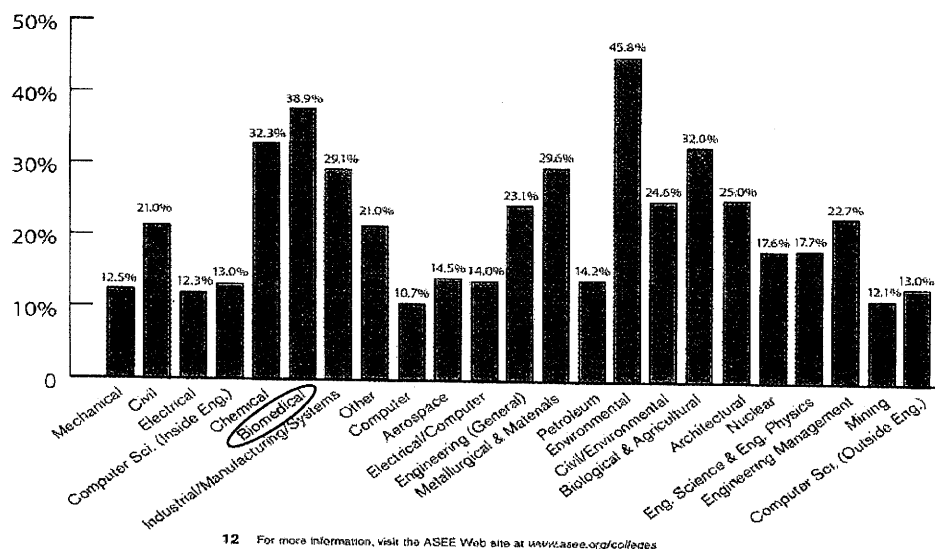


Figure 2. Percentage of Bachelor's Degrees Award to Women by Discipline (2012-2013)¹⁰

Although gender diversity is poor in engineering as a whole, the field of biomedical engineering has historically attracted more women than other engineering specialties. Approximately 40% of those receiving a B.S. degree in Biomedical Engineering are women, as shown in Figure 2. Therefore, adding this degree can help attract and recruit women, contributing to increasing the gender diversity of undergraduate engineering students at Virginia Tech.

In 2012, Forbes¹¹ ranked Biomedical Engineering as the number one major that was worth student's tuition, time, and effort: "These aren't majors that anyone could do. They're hard, ...there is high demand for them and a low supply of people with the skills, so it drives up the labor market price." Spontaneous inquiries and expressions of interest from potential students has been another indicator of student interest. The department has archived the numerous emails from potential students interested in pursuing a B.S. in Biomedical Engineering. Many of these students are high school juniors and seniors who are considering enrollment at Virginia Tech. These students voice disappointment when they hear that Virginia Tech does not offer a B.S. in Biomedical Engineering. Virginia Tech is potentially losing bright and talented students to other universities in the country due to a lack of availability of a B.S. in Biomedical Engineering. This potential loss also effects the Biomedical Engineering graduate program when the department has to spend extra funds on recruitment efforts to bring these highly sought- after students at other universities to Virginia Tech, as well as our graduates that wish to pursue a higher degree.

¹¹ Goudreau, J. (2012, May 15). The 15 Most Valuable College Majors. Retrieved from <http://www.forbes.com/sites/jennagoudreau/2012/05/15/best-top-most-valuable-college-majors-degrees/>

Market/Employer Demand

Analyses of every research and economic projection clearly indicate that the Biomedical Engineering field is a leading growth area. The following reports from news and journals show the critical motivating factors that justify the development of this undergraduate biomedical education program at Virginia Tech.

National Demand: The US News and World Report¹² reported that according to the U.S. Department of Labor, “employment of biomedical engineering is expected to grow by 62 percent between 2010 and 2020”. Additionally, the Bureau of Labor Statistics states: “Employment of Biomedical Engineers is projected to grow 27 percent from 2012 to 2022, much faster than the average for all occupations”. Other news sites such as Boston.com¹³ go on to say that “The aging of the population and a growing focus on health issues will drive demand for better medical devices and equipment designed by biomedical engineers.” Biomedical Engineering undergraduates often go on to pursue industry (1/3), medical school (1/3), or graduate school in engineering or law (1/3). As a degree, Biomedical Engineering is quickly becoming one of the most valuable majors with places like Forbes listing Biomedical Engineering as the No. 1 most valuable college major in America.¹⁴

Major news outlets and the Department of Labor are not the only ones noticing the growing trend in Biomedical Engineering. Several research journals have also published findings that support a future need for growth in Biomedical Engineering programs. The Annals of Biomedical Engineering¹⁵ found that:

“Financial opportunities, expansion of research applications for engineering methods and techniques to biomedical problems, and the associated eruption of the quantity and quality of quantitative life science investigations have driven the growth of academic BME programs. So, too, has intense student interest... Since 2010, 17 additional BME programs have been accredited ... with 92 accredited programs already, one can guess that over the next 25 years, the total number of ABET accredited undergraduate programs in the US may rise to a total of 150-175”

Another article that was published in Nature, spoke of the increased commercial interest of Biomedical Engineers. They noted that students are finding themselves with multiple job offers after graduation and that “Job prospects are bright in biomedical engineering (BME), which combines engineering design skills with biological expertise, and students are flocking to enter the field”.

¹² Engineering School Tips for Success. (2013, March 26). *US News and World Report*. Retrieved from: <http://www.usnews.com/education/best-graduate-schools/top-engineering-schools/articles/2013/03/26/engineering-school-tips-for-success-2>

¹³ Top 30 fastest-growing jobs by 2018. (2013, December 30). Retrieved from <http://www.boston.com/jobs/2013/12/27/top-fastest-growing-jobs/aUvFsEjhGN3iqQcNKohycM/story.html#slide-1>

¹⁴ 15 Most Valuable College Majors. (n.d.). Retrieved from <http://www.forbes.com/pictures/lmj45jgfi/no-1-biomedical-engineering/>

¹⁵ Hart, R. T. (2015). Biomedical Engineering Accredited Undergraduate Programs: 4 Decades of Growth. *Annals of biomedical engineering*, 1-3.




They go on to mention that because “biomedical engineering is made up of two fields that will never go away, and are constantly changing, and are in demand” biomedical engineers have key marketable qualities that companies such as medical-device manufacturers, pharmaceuticals, and the drug industry are “beginning to see the value of biomedical engineers....because they can move bioinformatics and computational biology forwards”.¹⁶ Additionally, an article published in the Journal of the American Medical Association (JAMA)¹⁷ stated: “At each juncture along the continuum from basic biomedical research to clinical research to improved health, it is imperative that our national clinical research expertise have adequate resources and infrastructure”. They went on to say that it is recommended that specific stakeholders “recognize biomedical informatics as a scientific discipline by creating educational programs and tenure track opportunities for researchers”.

Local Demand: On March 1, 2016, we issued a survey which polled all undergraduate College of Engineering (COE) students at Virginia Tech who are enrolled in the Biomedical Engineering Minor Program (total 171). The poll ask only 5 questions.

1. Gender
2. Ethnicity
3. Current Major
4. Expected graduation date
5. If BME was available as an undergraduate degree at VT, would you have pursued it?

Results were collected from 113 of the 171 students. There was a 47/53% of responses from males vs. female students, respectively. The results in Table 1 depict a strong interest in pursuing a BME BS at VT.

Table 1. Survey Questions #5: If BME was available as an undergraduate degree at VT, would you have pursued it? Results indicated significant interest in BME at VT.

#	Answer		Response	%
1	Yes		91	81%
2	Maybe		17	15%
3	No		5	4%
Total			113	100%

Without a Biomedical Engineering program, it is very likely that we will lose top quality students to other schools as they look for Biomedical Engineering programs. Historically, high school students and their parents have routinely asked about an undergraduate Biomedical Engineering programs and opportunities and have been disappointed to find out that only a graduate program and minor currently exists. In addition, Schools.com¹⁸ projects the career outlook for biomedical engineers in Virginia at 95.9%.

¹⁶ Gewin, V. (2003). Biomedicine meets engineering. *Nature*, 425(6955), 324-325.

¹⁷ Sung, N. S., Crowley Jr, W. F., Genel, M., Salber, P., Sandy, L., Sherwood, L. M. & Rimoin, D. (2003). Central challenges facing the national clinical research enterprise. *Jama*, 289(10), 1278-1287.

¹⁸ Rainey, K. (2014, June 9). Biomedical engineer salary & career outlook. Retrieved from <http://www.schools.com/news/biomedical-engineer-salary-career-outlook.html>

Additional Critical Motivational Factors:

- Increasing engineering diversity at Virginia Tech by recruiting at the undergraduate, graduate, and faculty levels: Approximately 40% of Biomedical Engineering students are female.
- Capitalizing on unprecedented biomedical growth at Virginia Tech through a range of new programs, institutes and partners will help create new jobs and technology.
- Virginia Tech COE is the only program in the top 50 across the U.S. without an undergraduate program in Biomedical Engineering. Adding a degree in Biomedical Engineering will also increase the university's rankings nationally.
- Increasing Biomedical Engineering faculty will increase research expenditures.
- Increasing philanthropic donations from individuals and companies with Biomedical Engineering interests and desires for better health.

Employment Demand

Biomedical Engineering has become one of the fastest growing fields of engineering worldwide. Biomedical engineers analyze and design solutions to problems in biology and medicine with the goal of improving the quality and effectiveness of patient care through jobs in universities, hospitals, manufactures, government agencies, and research facilities. A bachelor's degree in engineering is required for almost all entry-level engineering jobs. The Bureau of Labor Statistics ^{19,20} (BLS) states that employment of biomedical engineers is expected to grow by 62 % from 2010 to 2020 with about 5,200 new jobs over the next 10 years, much quicker than the average for all professions. It is projected that the demand will only increase as an aging population is likely to need more medical care which there will be a need from increased biomedical engineering advances. In 2012, BLS estimated 19,400 jobs in biomedical engineering for job seekers with a bachelor's degree. Job seekers with biomedical engineering bachelor degrees were reporting from \$41.81 per hour to a median of \$86,960+ per year at entry-level positions (Tables 2 and 3).

Table 2: Job Growth Projections (2012-2022) for Biomedical Related Occupations
(U.S. Bureau of Labor Statistics; accessed Sept. 2015)²¹

Job Title	SOC Code	Employment 2012	Projected Employment 2022	Percentage Change	Median Annual Wages 2012	Typical Entry-Level Education
Biomedical Engineers Biomechanical Biochemical Biomedical Dialysis Genetic	17-2031	19,400	24,600	26.6%	\$86,960	Bachelor's Degree

Table 3: Job Growth Projections (2010-2020) For Biomedical-Related Occupations
(Virginia Employment Commission)

Job Title	SOC Code	Employment 2010	Projected Employment 2020	Total Percentage Change	Annual Percentage Change
Biomedical Engineer	17-2031	462	905	95.9%	7%

Resource Needs / Savings

The newly created BME program will launch with a fixed class size of 40 students per year. Based on the current faculty to student class ratio of 8:1, we anticipate to hire 2 new faculty members and 2 new instructors to help cover the required courses. The BME degree student class size may change based on a yearly evaluation of student demand and departmental resources. The BEAM department future resources will be subject to the new budgeting models being developed by the University.

RESOURCE	ESTIMATED COSTS (use NA if not applicable)
Faculty	\$429,600 (salary and benefits for 2 faculty and 2 instructors)
Administrative Staff	NA
Graduate Teaching/ Graduate Research Assistants	NA
Space	Shared use of general assigned space
Library	NA
Equipment	\$700,000 (part of startup)
Other	NA

¹⁹ Occupational Outlook Handbook. (n.d.). Retrieved from: <http://www.bls.gov/ooh/architecture-and-engineering/biomedical-engineers.htm>

²⁰ Occupational Employment and Wages, May 2014, 17-2031 Biomedical Engineers. (n.d.). Retrieved from: <http://www.bls.gov/oes/current/oes172031.htm>

²¹ Employment Projections. (n.d.). Retrieved from: <http://data.bls.gov/projections/occupationProj>

Appendix A: Sample Plans of Study

COLLEGE OF ENGINEERING - DEPARTMENT OF BIOMEDICAL ENGINEERING AND MECHANICS
BACHELOR OF SCIENCE IN BIOMEDICAL ENGINEERING
 FOR STUDENTS GRADUATING IN CALENDAR YEAR 2020
 122 CREDITS REQUIRED FOR GRADUATION

FALL SEMESTER FRESHMAN 2016		Credits	SPRING SEMESTER FRESHMAN 2017		Credits
CHEM 1035 General Chemistry <i>Co: MATH 1025 or MATH 1225</i>		3	ENGL 1106 First-Year Writing <i>Pre: ENGL 1105</i>		3
CHEM 1045 General Chemistry Lab <i>Co: CHEM 1035</i>		1	MATH 1226 Calculus of a Single Variable <i>Pre: MATH 1225</i>		4
ENGL 1105 First-Year Writing		3	MATH 2114 Introduction to Linear Algebra <i>Pre: MATH 1225 (minimum grade of B) or MATH 1226</i>		3
MATH 1225 Calculus of a Single Variable (C-) <i>Pre: Math Ready</i>		4	PHYS 2305 Foundations of Physics I <i>Pre: (MATH 1205 or MATH 1205H or MATH 1225) or (MATH 1206 or MATH 1206H or MATH 1226)</i>		4
ENGE 1215 Foundations of Engineering (C-) <i>Co: MATH 1225</i>		2	ENGE 1216 Foundations of Engineering (C-) <i>Pre: ENGE 1215</i>		2
CLE (Areas 2, 3, or 7) ¹		3			
TOTAL		16	TOTAL		16
FALL SEMESTER SOPHOMORE 2017		Credits	SPRING SEMESTER SOPHOMORE 2018		Credits
BIOL 1105 Principles of Biology ⁷ <i>Co: BIOL 1115</i>		3	BMES 2104 Introduction to Biomedical Engineering ⁶ <i>Pre: ENGE 1216, PHYS 2305 Co: MATH 2214</i>		3 ^[F]
MATH 2204 Introduction to Multivariable Calculus <i>Pre: MATH 1226</i>		3	ESM 2204 Mechanics of Deformable Bodies <i>Pre: ESM 2104, (MATH 2224 or MATH 2224H or MATH 2204 or MATH 2204H)</i>		3
MATH 2214 Introduction to Differential Equations <i>Pre: MATH 1114 or 2114, MATH 1226</i>		3	ESM 2304 Dynamics <i>Pre: ESM 2104, (MATH 2224 or MATH 2224H or MATH 2204 or MATH 2204H), Co: MATH 2214</i>		3
ESM 2104 Statics <i>Co: MATH 2224 or MATH 2224H or MATH 2204 or MATH 2204H or MATH 2406H</i>		3	MSE 2034 Elements of Materials Engineering <i>Pre: CHEM 1035, Co: PHYS 2305</i>		3
PHYS 2306 Foundations of Physics I with lab <i>Pre: MATH 1226, PHYS 2305</i>		4	ECE 3054 Electrical Theory <i>Pre: PHYS 2306, Co: MATH 2214</i>		3
TOTAL		16	TOTAL		15
FALL SEMESTER JUNIOR 2018		Credits	SPRING SEMESTER JUNIOR 2019		Credits
BMES 3024 BME Cellular Lab and Design ⁶ <i>Pre: BMES 2104</i>		2 ^[F]	BMES 3034 Bioinstrumentation Laboratory & Design for Living Systems ⁶ <i>Pre: BMES 2104</i>		2 ^[S]
ESM 3234 Fluid Mechanics I – Control Volume Analysis <i>Pre: ESM 2304, PHYS 2306</i>		3 ^[F]	BMES 3184 Problem Solving in BME ⁶ <i>Pre: BMES 2104</i>		3 ^[S]
BMES/BMVS 4064 Introduction to Medical Physiology ⁶ <i>Pre: Junior Standing</i>		3 ^[F]	BMES Technical Elective ⁴		3
STAT Course ²		3	Technical Elective ⁵		3
CLE (Area 2, 3 or 7)		3	CS Programming Course ³		3
TOTAL		14	TOTAL		14
FALL SEMESTER SENIOR 2019		Credits	SPRING SEMESTER SENIOR 2020		Credits
BMES 4015 BME Senior Design and Project ⁶ <i>Pre: BMES 3184</i>		3 ^[F]	BMES 4016 BME Senior Design and Project ⁶ <i>Pre: BMES 4015</i>		3 ^[S]
BMES 4134 Global, Societal and Ethics in BME ⁶		3 ^[F]	BMES Technical Elective ⁴		3
BMES Technical Elective ⁴		3	BMES Technical Elective ⁴		3
Technical Elective ⁵		3	Technical Elective ⁵		3
CLE (Area 2, 3 or 7)		3	CLE (Area 2, 3 or 7)		3
CLE (Area 6)		1			
TOTAL		16	TOTAL		15

¹ A total of 6 hours of Area 2 and 6 hours of Area 3 courses must be completed. Only selected courses can simultaneously satisfy both Area 2/3 & 7 requirements. Use extra care when selecting this course.

² STAT course chosen from: STAT 3615, STAT 4604

³ CS programming course chosen from: CS 1044, CS 1064, or CS 1114

⁴ BMES Technical Electives may be chosen from those listed on the Approved Technical Electives list on page 4 of checksheet

⁵ Technical Electives may be chosen from those listed on the BMES Electives list on page 3 of checksheet

⁶ Course satisfies BMES degree core requirement

⁷ BMES students are not required to take BIOL 1115 as a co-requisite to BIOL 1105

Curriculum for Liberal Education (CLE)

Consult the CLE Alphabetical Listing at: <http://www.cle.prov.vt.edu/guides/alpha.html>, CLE courses need to be completed prior to graduation

CLE Area 1: Writing and Discourse (6 hrs)	ENGL 1105	(3)	ENGL 1106	(3)
CLE Area 2: Ideas, Cultural Traditions, Values Electives (6 hrs)		(3)		(3)
CLE Area 3: Society & Human Behavior electives (6 hrs)		(3)		(3)
CLE Area 4: Scientific Reasoning and Discovery (8 hrs)	PHYS 2305	(4)	PHYS 2306	(4)
CLE Area 5: Quantitative and Symbolic Reasoning (8 hrs)	MATH 1225	(4)	MATH 1226	(4)
CLE Area 6: Creativity & Aesthetic Experience elective (1 hr)				(1)
CLE Area 7: Global Issues Elective (3 hrs) ¹				(3)

If a CLE course is double-counted to satisfy two different CLE areas, a free elective(s) must be taken to maintain a minimum of 122 credits.

¹A total of 6 hours of Area 2 and 6 hours of Area 3 courses must be completed. Only selected courses can simultaneously satisfy both Area 2, 3, and 7 requirements. Use extra care when selecting this course.

Electives:

Biomedical Engineering (BMES) Technical Electives (12 credit hours required)

Any 3-credit BMES 3/4/5000-level course not otherwise used to fulfill a BME requirement can be used as a technical elective. BMES Technical Electives may be chosen from the approved list on page 4 of the checksheet.

Technical Electives (9 credit hours required)

An approved 2/3/4000-level course in another discipline that has significant technical content relevant to the science or application of biomedical engineering can be used as a technical elective. Technical Electives may be chosen from the list on page 3 of the checksheet.

Change of Major Requirements: For change of major requirements, please see:

<http://www.enge.vt.edu/undergraduate/undergraduate-changing-majors>

Foreign Language Requirements: Students must have had 2 years of a foreign language in high school or one year at the college level (6 credit hours) of the same language. College-level credits used to meet this requirement do not count towards the degree.

Satisfactory Progress Towards Degree: University Policy 91 outlines university-wide minimum criteria to determine if students are making satisfactory progress towards the completion of their degrees. The BME Department fully supports this policy. Specific expectations for satisfactory progress for Biomedical Engineering majors are as follows:

- Each student must meet the minimum University-wide criteria as described in Policy 91 and summarized in the Undergraduate Catalog (under Academic Policies)
- After having completed 72 credit hours (including transfer, advanced placement, advanced standing, and credit by examination) must have:
 - Maintain an in-major GPA (in-major GPA is calculated using all courses taught under the BMES designator) and an extended in-major GPA (extended in-major GPA is calculated using all BMES courses and ESM 2104, 2204, and 2304) of 2.0 or better
 - Complete a minimum of 12 credits that apply toward the BME degree per academic year (including summer and winter sessions).

Statement of Hidden Pre-requisites:

- There are no hidden pre-requisites in this program of study.
- Pre-requisites may change from what is indicated. Be sure to consult the University Catalog or check with your advisor for most current requirements.

Graduation Requirements: Each student must complete at least 122 semester credit hours with a minimum overall GPA of 2.00 and a minimum in-major GPA of 2.00.

Note: This will be replaced by the Pathways Curriculum if it is approved by the start of this proposed program.

Appendix A-2: BMES Technical Electives*

BMES 3124 – Introduction to Biomechanics *Pre: BMES 2104, ESM 2204, ESM 2304*

BMES 3134 – Introduction to BME Imaging *Pre: BMES 2104, (MATH 2204 or 2204H), PHYS 2306*

BMES 3144 - Biomedical Devices *Pre: BMES 2104*

Students in their senior year, with 3.0 or better GPA, may enroll in 5000-level courses satisfying undergraduate degree requirements within their department's with the permission of the course instructor and the Department Head.

BMES 5054 – Quantitative Cell Physiology *Co: BMES 5044*

BMES 5064 – Quantitative Organ Systems Physiology *Co: BMES 5044*

BMES 5024 (cross-listed with BMVS 5224) – BME and Human Disease *Pre: BMES 5004 or BMES/BMVS 4064*

BMES 5044 (cross-listed with BSE 5044 and CHE 5044)– Engineering Mathematics

BMES 5124 (cross-listed with ESM 5224)– Advanced Musculoskeletal Biomechanics

BMES 5184 – Injury Physiology *Pre: BMES 5004, Co: BMES 5164*

BMES 5314 – Introduction to Regenerative Medicine

BMES 5714 – Biomedical Microdevices

*** New courses will be developed as the demand grows.**

Appendix A-3: Approved Technical Electives

Students choose from the courses listed below, noting that some courses are not available to all students because some courses have prerequisites and some are restricted to majors in the offering department.

BCHM 3114	Biochemistry for Biotechnology and the Life Sciences	ESM 4245- ESM 4246	Mechanics of Animal Locomotion
BIOL 2004	Genetics	ESM 4304	Hemodynamics
BIOL 3134	Human Genetics	HNFE 3634	Epidemiologic Concepts of Health and Disease
BIOL 4704	Immunology	HNFE 3824	Kinesiology
BIOL 4734	Inflammation Biology	HNFE 4844	Exercise and Neuromuscular Performance
BMVS/BCHM 4034	Environmental Health Toxicology	ISE 3614	Human Factors Engineering and Ergonomics
BMVS 4054	Laboratory Animal Management	ISE 4624	Work Physiology
BMVS 4074	Pharmacology	MATH 3214	Calculus of Several Variables
BSE 3534	Bioprocessing Engineering	MATH 4234	Elementary Complex Analysis
BES 4544/ CHE 4544	Protein Separation Engineering	MATH 4445- MATH 4446	Introduction to Numerical Analysis
CHE 4104	Processing Materials	ME 4034	Bio-inspired Technology
CHE 4304 (ME 4344)	Biological Transport Phenomena	ME 4524	Introduction to Robotics and Automation
CHEM 2535- CHEM 2536	Organic Chemistry	ME 4864	Micro/Nano-Robotics
CHEM 2545- CHEM2546	Organic Chemistry Laboratory	MSE 4164	Principles of Materials Corrosion
CHEM 4554	Drug Chemistry	MSE 4304	Metals and Alloys
CS 3824	Introduction to Computational Biology and Bioinformatics	MSE 4574	Biomaterials
CS 4884	Computational Biology and Bioinformatics Capstone	MSE 4584	Biomimetic Materials
ECE 4580	Digital Processing Imaging	MSE 4614	Nanomaterials
ECE 4624	DSP and Filter Design	NEUR 3044	Cellular and Molecular Neuroscience
ECE 4405-ECE 4406	Control Systems	PHYS 3324	Modern Physics
ESM/MSE 3054	Mechanical Behavior of Materials	PHYS 3405- PHYS 3406	Intermediate Electricity and Magnetism
ESM 4024	Advanced Mechanical Behavior of Materials	PHYS 4455- PHYS 4456	Introduction to Quantum Mechanics
ESM 4044	Mechanics of Composite Materials	PHYS 4504	Introduction to Nuclear and Particle Physics
ESM 4105- ESM 4106	Engineering Analysis of Physiologic Systems	PHYS 4574	Nanotechnology
ESM 4204	Musculoskeletal Biomechanics	PHYS 4614	Optics
ESM 4224	Biodynamics & Control	PHYS 4714	Introduction to Biophysics
ESM 4234	Mechanics of Biological Materials and Structures		

Department Letters of Support

1. Chemistry
2. English
3. Math
4. Engineering Education
5. Physics
6. Biology
7. Material Science Engineering
8. Electrical Engineering
9. Computer Science
10. Statistics
11. Chemical Engineering
12. Mechanical Engineering
13. Biological Systems Engineering
14. Neuroscience
15. Biomedical Sciences and Pathobiology
16. Human Nutrition, Food and Exercise



VirginiaTech.

College of Science

Department of Chemistry (MC0212)

2103 Hahn Hall South
Blacksburg, Virginia 24061
540-231-3090
email: gyee@vt.edu
www.chem.vt.edu

December 17, 2015

Pam VandeVord
BEAM
Associate Department Head for Undergraduate Studies
BEAM (0194)
Virginia Tech

Dear Pam,

The Department of Chemistry supports the use of CHEM 1035 and 1045 General Chemistry as the required chemistry course for Biomedical Engineers. We also support listing CHEM 1036, General Chemistry, CHEM 1046 General Chemistry Lab, CHEM 2535/2536 Organic Chemistry, CHEM 2545/2546 Organic Chemistry lab and CHEM 4554 Drug Chemistry as electives. This is based on an estimate of 12 students per year. If a student is pre-med, he/she will have to have all but the Drug Chem course and this represents a fairly significant request because of the labs. We can support this conditionally until we know the true numbers, but as circumstances change, we would have to revisit the question and hope that we can count on you for support of a request for additional resources.

Regards,

Gordon T. Yee
Associate Professor
Director of Undergraduate Programs

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2. English

Ginney Fowler <gfowler@vt.edu>

to Pam Hooks -

12/11/15

Dear Dr. VandeVord:

The English department is happy to have you include English 1105, 1106, (and 1204H) on your check sheet.

Ginney Fowler

Virginia C. Foster
Professor & Director of
Undergraduate Studies
in English
313 Shields Hall
Virginia Tech
Blacksburg, VA 24061-0112
(540) 231-6939 (o) (540) 381-1358 (h)

<Checksheet BMES_Draft.pdf>

3. Math

Pam VandeVord <pvard@vt.edu>

to Peter -

Jan 6

Hi Peter

I am following up on the request for a support letter from your department for the use of

MATH 1225, 1226, 2114, 2204, 2214 as our required MATH series (with the correction to include 2 pre-reqs for 2114).

and the use MATH 3214, 4574, 4445-4446 as technical electives

Peter Haskall <phaskall@math.vt.edu>

to Pam -

Jan 6

Dear Pam,

Thank you for writing me about your efforts to introduce a Biomedical Engineering B.S. degree that will include Math 1225, 1226, 2114, 2204, and 2214 as required courses and will include Math 3214, 4574, 4445, and 4446 as technical electives. Offering this degree strikes me as an excellent idea, which the Math Department will support to the extent possible. If the degree does not result in an increased number of COE students, it is likely that the degree will not significantly increase enrollment in math courses. Most COE degrees require the courses you plan to require, and the large number of technical electives you plan to list will make it likely that your students will be distributed lightly across a large number of technical elective courses. We'll monitor enrollments; if they don't increase, we will not require additional resources. To the extent that university policies lead to significant increases in math enrollments, we'll be able to serve all students only if we receive resource increases commensurate with the enrollment increases. I make this point not because your immediate plans suggest that I should expect increased enrollments, but only because these days I hear much encouragement to use new degrees to increase enrollments but I hear nothing about realistic plans to support the teaching that larger numbers of students will require.

4. Engineering Education

Pam VandeVord <pvard@vt.edu>

to Tamara, Stephanie -

12/11/15

Hello Stephanie and Mara

As you may already know, the Biomedical Engineering and Mechanics Department is developing a new BS degree in Biomedical Engineering. Our curriculum committee has been working hard to construct a solid group of courses that will educate a new generation of biomedical engineers. In doing so, we have found courses within your department which would strengthen the curriculum.

Similar to all other COE students, we would like to use ENGE 1215 and 1216 as our required Eng Foundations series.

We need your approval before listing them on our checksheet within the BME BS proposal. I have attached a draft version of the proposed checksheet for you to review; but please keep in mind this is a draft and we would appreciate you only circulating to those who you feel need to help in the decision process.

After reviewing, please let me know if your department would you be able to support the use of the courses (listed below) within the BME BS degree curriculum. We are hoping to have the proposal to the COE UCC this January. Your support would be greatly appreciated. If you have any questions or concerns, I would be happy to meet and discuss with you.

Thanks

Pam

Required Courses:



Ken Reid <kreid@vt.edu>

to Pam, Tamara, Stephanie -

12/18/15

Pam: Mara forwarded the attached message to me. This looks like an addition to any BS degree in engineering that we would expect; we would assume ENGE 1215 & 1216 to be a part of the program.

Please consider the request to be approved. Please let me know if there are any questions or concerns.

Thanks -

Ken

On Fri, Dec 18, 2015 at 7:44 AM, Tamara Knott <taknott@vt.edu> wrote:

Tamara Knott
Associate Professor
Engineering Education



VirginiaTech

College of Science

Department of Physics

Blacksburg, Virginia 24061

540-231-8740 Fax: 540-231-7511

E-mail: jhs@vt.edu

January 15, 2016

Dear Colleagues,

This letter is in support of the proposal for a new BS degree in Biomedical Engineering. The Physics Department has no problem with including in this degree the required introductory Physics courses (PHYS 2305 and 2306) and the list of physics technical electives at the 3000 and 4000 level.

Sincerely,

John H. Simonetti
Professor, Associate Chair of Physics
Virginia Tech

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College of Science

Department of Biological Sciences
2089 Derring Hall (0406)
Blacksburg, Virginia 24061
540/231-3803 Fax: 540/231-9307
E-mail: rawalker@vt.edu
www.biology.vt.edu

January 12, 2016

Pamela VandeVord, Ph.D.
Department of Biomedical Engineering & Mechanics

Dear Dr. VandeVord,

The Department of Biological Sciences supports inclusion of BIOL 1105 Principles of Biology as a required course on the checksheet for the BS degree in Biomedical Engineering. Please note our ability to provide seats in BIOL 1105 is dependent on continued enrollment support funds.

We also support the inclusion of the following courses as technical electives on the same checksheet:

BIOL 2004: Genetics
BIOL 3134: Human Genetics
BIOL 4704: Immunology
BIOL 4734: Inflammation Biology

Please be sure students in the Biomedical Engineering BS degree are informed that one or more prerequisites are required for each of these technical elective courses and that prerequisite checking is enforced for our courses. Inclusion of these BIOL courses is not an indication that prerequisites will be waived for students in the Biomedical Engineering BS degree.

Sincerely,

Richard A. Walker
Associate Head
Department of Biological Sciences

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7. MSE

Pam Vandevord <pvord@vt.edu>
to David Robert Hendrickson <drhend@vt.edu>
Hi Dr Hendrickson

Jan 6

Happy New Year!

I wanted to follow-up with you regarding the use of your courses for BME degree. Would you be able to send me a support letter for the use of MSE 2034 as a required and MSE 4164, 4304, 4574 and 4584 as technical electives? Also if you are not the correct faculty member to address this request, can you please forward to the correct person?

Thanks



Robert Hendricks <rhendrv@mse.vt.edu>
to Susan, Michelle, Pam <pvord@vt.edu>
Hi:

Jan 6

I have talked to our Undergrad CC chair and he agrees that we will be happy to allow your students in these courses, assuming they have all the prerequisites. If the prerequisite is an MSE course, we will also approve the student for that course.

Bob

8. ECE

Jaime De La Rea <jmlare@vt.edu>
to Jason, Pam <pvord@vt.edu>
Pam

Jan 13

Happy New Year.

I have spoken with Dr. Xuan. He teaches ECE 4580 and he is OK with including students from your department if space is available.

Also, you can include ECE 3054 in the list of Tech Electives.

Sorry for the delay, I was waiting for answers.

Best

Jaime

Dr. Jaime De La Rea
Associate Department Head and Associate Professor
ECE Department
Virginia Tech
Blacksburg, VA 24061-0111
(540) 231-8625 Office
(540) 231-3362 FAX
(540) 231-2277 Mail

9. Computer Science

Pam Vandevord <pvord@vt.edu>
to Cal <cal@vt.edu>
Hi Cal:

Jan 8

Happy New Year!

I wanted to follow-up with you regarding the use of the courses for BME degree. Would you be able to send me a support letter for the use of

CS 1044, 1054 or 1114 as our required course and
CS 3624 for the technical elective?

And BTW: congrats on becoming Department Head! Does this mean that someone will be running the UCC?

Pam

On Wed, Dec 9, 2015 at 2:03 PM, Cal Ribbens <calribbens@vt.edu> wrote:

Pamela Vandevord, Ph.D.
Professor
Program Chair Biomedical Engineering
Department of Biomedical Engineering & Mechanics
447 Kelly Hall

Cal Ribbens <calribbens@vt.edu>
to Pam <pvord@vt.edu>
Pam

Jan 6

Thanks! Sorry that I was not in my class!

Yes, there will be a new chair for the college curriculum chair.

Cal

Ronald D. Fricker, Jr.
Head, Department of Statistics
Hutcheson Hall, room 406-A, Virginia Tech
Blacksburg, Virginia 24061
540-231-7754
rf@vt.edu

February 5, 2016

To whom it may concern:

The Department of Statistics is pleased to offer our conditional support for the proposed Bachelor of Science in Biomedical Engineering to be housed in the Virginia Tech Biomedical Engineering and Mechanics Department. We are excited about the promise this interdisciplinary field holds for the advancement of knowledge about the application of engineering analysis and design to clinical applications, including the considerable synergistic opportunities for research collaboration between the school and our department.

The Biomedical Engineering degree check sheet lists STAT 3615 as a required majors course. We support the inclusion of this course as part of the Biomedical Engineering degree program, though we must note that the Department of Statistics is facing increasing enrollment pressure on all of our classes, and in particular STAT 3615 which is currently significantly over-subscribed and under-resourced.

Thus, our support of this new degree is conditional on additional resources being provided to the Statistics Department so that we have the capacity to support the additional students. In particular, each additional STAT 3615 class (consisting of 60 students) will require funding for a GTA step 10 stipend and tuition waiver for the semester in which the section is taught, and these resources will need to be committed to in advance and available beginning the first year Biomedical Engineering students can enroll.

Of course, we are aware that a new funding model is under development by the Office of the Provost to support this kind of service teaching and that it may be in place by the time this degree begins enrolling students. However, in the absence of any specific funding model details, we must emphasize that without the funding just described we do not have the resources to support these students. Furthermore, at the expense of stating the obvious, a funding model in which resources lag enrollment is untenable in a situation like this where we expect to have to support multiple new sections of STAT 3615 as soon as the program is approved.

That said, we are excited to be a part of this innovative educational initiative that promises to produce graduates with skills valuable to the advancement of engineering, medicine, and societal well-being. We offer our conditional support to the program and we look forward to the opportunities for research collaboration between Department of Statistics faculty and the Biomedical Engineering and Mechanics Department faculty.

Sincerely,



R.D. Fricker, Jr.
Professor and Head,
Department of Statistics

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VirginiaTech

College of Engineering

Aaron S. Goldstein
Associate Professor
Department of Chemical Engineering
133 Randolph Hall (0211)
Blacksburg, Virginia 24061
540/231-3674 Fax: 540/231-5022

14 December, 2015

Dear Pam,

This letter is to indicate that the Chemical Engineering Department approves the listing of CHE 4104 Process Materials and CHE 4304/ME 4344 Biological Transport Phenomena as technical electives for the BME major. Please advise your students that entry into these courses will be contingent on their meeting the listed course prerequisites (or equivalent courses).

No additional resources are requested.

Please feel free to contact me at 540-231-3674 or by email at goldst@vt.edu if you have any additional questions.

Sincerely,

Aaron S. Goldstein, Associate Professor
Assistant Department Head
Department of Chemical Engineering
Virginia Polytechnic Institute and State University
Blacksburg, Virginia 24061-0211

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12. ME

Pam VandeVord <pvord@vt.edu>

to Clinton

12/10/15

Hello Clint

As you may already know, the Biomedical Engineering and Mechanics Department is developing a new BS degree in Biomedical Engineering. Our curriculum committee has been working hard to construct a solid group of courses that will educate a new generation of biomedical engineers. In doing so, we have found courses within your department which would strengthen the curriculum. *These course would only be used as technical electives, thus limiting the students who would take them.* We need your approval before listing them on our checklist as 'approved technical electives' within the BME BS proposal.

I have attached a draft version of the proposed checklist for you to review, but please keep in mind this is a draft and we would appreciate you only circulating to those who you feel need to help in the decision process.

After reviewing, please let me know if your department would be able to support the use of the courses (listed below) within the BME BS degree curriculum. We are hoping to have the proposal to the COE UCC this January. Your support would be greatly appreciated. If you have any questions or concerns, I would be happy to meet and discuss with you.

thanks

Pam

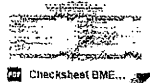
Courses:

ME 3304: Heat and Mass Transfer

ME 4034: Bio-Inspired Technology

ME 4524: Introduction to Robotics and Automation

ME 4864: Micro/Nano-Robotics



Checksheet BME...

Clinton Dancy <cln@vt.edu>

to Pam

12/15/15

Pam, With the exception of ME 3304 we approve of you listing the other courses as Technical Electives on your Biomed Degree Checksheet. Do not list ME 3304. It is a required ME course with prerequisites and we are not in a position to accept more students in this course.

I will qualify our approval for the other courses so that you understand that all of these courses are very popular with ME students and they tend to have limited enrollment capacity. So, ME students will get priority. If there is room we will accept non-majors such as your students, but enrollment in these courses is not guaranteed. If you have questions let me know.

Best wishes for the holidays.

Clint

13. BSE

Tess Thompson <thwynn@vt.edu>

to Pam

Jan 5

Hi Pam

Happy New Year to you as well!

We discussed this and we approve listing the following two courses as technical electives for a BS degree in biomedical engineering:

BSE 3534 Bioprocess Engineering

BSE 4544/CHE 4544 Protein Separation Engineering

Please note the change in the course number for BSE 4504 to BSE 3534, due to some adjustments in our biomolecular engineering curriculum.

You may also wish to consider a new course, BSE 4564 Metabolic Engineering, as a technical elective. Attached is the course proposal.

Tess

Tess Thompson, PhD

Associate Professor

Assistant Department Head for Undergraduate Studies

Biological Systems Engineering, Virginia Tech



VirginiaTech

College of Science

Office of the Dean (0405)

College of Science
North End Center, Suite 4300, Virginia Tech
300 Turner Street NW
Blacksburg, Virginia 24061
540/231-5422 Fax: 540/231-3380
www.science.vt.edu

December 18, 2015

Pamela VandeVord
Program Chair, Biomedical Engineering
Department of Biomedical Engineering & Mechanics
Virginia Tech

Dear Dr. VandeVord,

The Neuroscience program supports your request to include NEUR 3044 Cellular and Molecular Neuroscience and 3084 Cognitive Neuroscience as elective courses for the Bachelor of Science in Biomedical Engineering degree. Since these are required courses for all Neuroscience majors and with the demand growing, first preference for enrollment in these courses will be given to Neuroscience majors. Biomedical Engineering students in the Biomedical Engineering degree will be able to enroll in these NEUR courses subject to availability.

Sincerely,

Harald Sontheimer
I.D. Wilson Chair and Professor
Executive Director, School of Neuroscience

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15. BMVS

Ahmed, S <ansrahmd@vt.edu>
to Pamela, Angela, Becky ▾

Jan 6

Hello Pam,

Happy New Year!

Our college does not see any problem. However, the only active one is BMVS 4954 that is taught by Dr. David Moore. We are in the process of recruiting faculty, there is a potential (not certain) that some of the recruits may be interested in team-teaching the other two courses. I will keep you informed. Best, Ansar

From: <pamvond@gmail.com> on behalf of Pam Vandevord <pvond@vt.edu>

Date: Wednesday, January 6, 2016 at 11:26 AM

To: Microsoft Office User <ansrahmd@vt.edu>, "Webb, Angela" <awwebb@vt.edu>

Subject: Fwd: Request to use courses within BME BS degree as technical electives

16. HNFE



Selberg-Eaton, Renee <rselberg@vt.edu>
to Pamela, Matthew ▾

Jan 13

Hi Matt and Pam,

I'm not able to see the syllabus right now, but as long as the students have appropriate background I don't see an issue with adding these to your check sheet.

Renee S. Eaton
Sent from my iPhone

<BMVS-BMES4064_Fall15+Final4.pdf>

**COVER SHEET - NEW and REVISED CHECKSHEETS, OPTIONS, CONCENTRATIONS
and DEGREES**

Commission on Undergraduate Studies and Policies/ Commission on Graduate Studies and Policies
Effective September 2010

•SEE APPENDIX FOR NOTES, EXPLANATIONS AND ADDITIONAL GUIDELINES•
•PRINT CLEARLY, TYPE or COMPLETE ELECTRONICALLY•

PROPOSAL DATE: 03/29/16

15-DAY REVIEW END DATE:

DEPARTMENT: Biomedical Engineering and Mechanics

DEGREE NAME: Biomedical Engineering

☒ **MAJOR** ☐ **MINOR** ☐ **OPTION/CONCENTRATION**

☐ **GRADUATE CERTIFICATE** ☐ **UNIVERSITY CONCENTRATION**

DEAN and/or

DEPARTMENTAL CONTACT: Pam VandeVord

CONTACT

MAILCODE: 0298

CONTACT PHONE: 540-231-1994

CONTACT E-MAIL: pvord@vt.edu

CHECK ONLY ONE OF THE FOLLOWING BOXES

- | | | |
|--|--|---|
| <input type="checkbox"/> NEW UNDERGRADUATE CHECKSHEET | <input type="checkbox"/> REVISED CHECKSHEET [Revision>20%____ Revision<20%____]
(Attach copy of current APPROVED checksheet) | |
| <input type="checkbox"/> NEW MINOR | <input type="checkbox"/> REVISED MINOR
(Attach copy of current APPROVED checksheet) | <input type="checkbox"/> DISCONTINUED MINOR
(Attach Transition Plan) |
| <input type="checkbox"/> NEW OPTION | <input type="checkbox"/> REVISED OPTION
(Attach copy of current APPROVED checksheet) | <input type="checkbox"/> DISCONTINUED OPTION
(Attach Transition Plan) |
| <input type="checkbox"/> NEW UNIVERSITY CONCENTRATION | <input type="checkbox"/> REVISED UNIVERSITY CONCENTRATION
(Attach copy of current APPROVED checksheet) | <input type="checkbox"/> DISCONTINUED UNIVERSITY CONCENTRATION
(Attach Transition Plan) |
| <input type="checkbox"/> NEW CONCENTRATION | <input type="checkbox"/> REVISED CONCENTRATION
(Attach copy of current APPROVED checksheet) | <input type="checkbox"/> DISCONTINUED CONCENTRATION
(Attach Transition Plan) |
| <input type="checkbox"/> NEW GRADUATE CERTIFICATE | <input type="checkbox"/> REVISED GRADUATE CERTIFICATE | |
| <input checked="" type="checkbox"/> NEW DEGREE | <input type="checkbox"/> REVISED DEGREE | <input type="checkbox"/> DISCONTINUED DEGREE
(Attach Transition Plan) |

• **EFFECTIVE DATE: GRADUATING CLASS OF 2020** (List Year Only)

- **FOR ALL CHECKSHEETS, NEW AND REVISED:** Attach Statement from Dean or Departmental Representative Outlining the Changes from the Currently APPROVED Checksheets and Method(s) of Communication to Students Impacted by these Changes.
- **Attach Appropriate Letters of Support from Affected Departments and/or Colleges**
- **Revised checksheets with 20% or less revision can be forwarded directly to the Office of the University Registrar (0134) for Administrative Approval. Supporting documentation should be attached.**

Revision Summary:

APPROVAL SIGNATURES

Department Representative

Pamela VandeVord

Date: 3/29/16

College Curriculum Committee Representative

S. Caceran/cb

Date: 4/14/16

College Dean

Doreen A. Sturgeon/ch

Date: 4/14/16

January 18, 2016

Memorandum

To: COE Undergraduate Curriculum Committee

From: Department of Biomedical Engineering and Mechanics

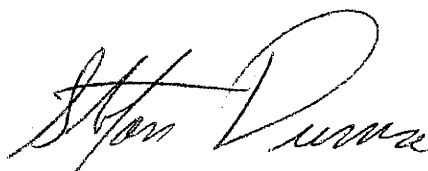
Subject: Support for new B.S. degree program in Biomedical Engineering

Please find the attached proposal for the development of a new B.S. in Biomedical Engineering. The BME Undergraduate Curriculum Committee has reviewed and approved the proposed curriculum described in the following proposal. In addition, all courses within the proposed checksheet have been approved by their departments to be included in the curriculum (Support letters are included). Required resources are also described within the document.

Sincerely,



Pamela Vandevord
BME Program Chair
Professor



Stefan Duma
BEAM Department Head
Harry C. Wyatt Professor

Invent the Future

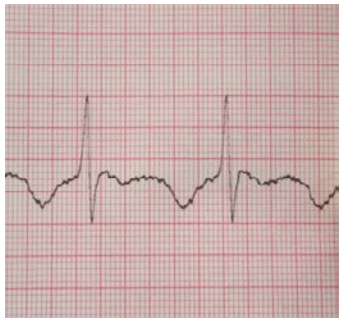
Bachelor of Science Degree in Biomedical Engineering Presentation to the Board of Visitors, Academic Affairs Committee April 3, 2017



Pamela VandeVord, Professor and Interim Department Head, BEAM

What is Biomedical Engineering?

Applying engineering analysis and design to clinical applications in order to improve the quality of life



© 2000 How Stuff Works
Photo courtesy of Intuitive Surgical

- 1 Surgeon Console
- 2 Image Processing Equipment
- 3 Endowrist Instruments
- 4 Surgical Arm Cart
- 5 Hi-Resolution 3-D Endoscope



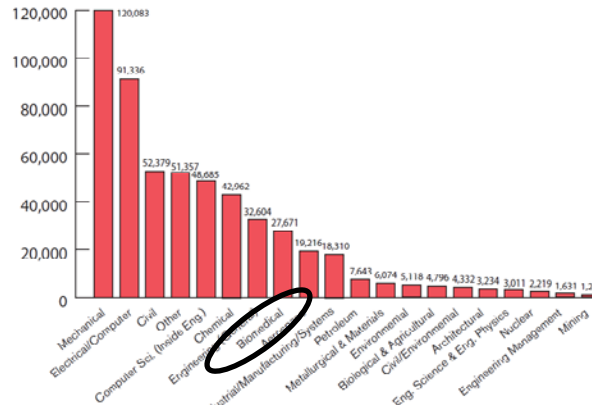
What is the Demand for Biomedical Engineers?

“27% job growth from 2012-2022. This is more than double the 11% outlook for all occupations”

“employment of biomedical engineers is expected to grow by 62 % from 2010 to 2020, much quicker than the average for all engineering professions”

US Department of Labor Statistics

UNDERGRADUATE ENROLLMENT BY DISCIPLINE: 543,942*



* Enrollment is for full-time bachelor's degree candidates in engineering. Total does not include Computer Science (outside engineering)

19 For more information, visit the ASEE Web site at www.asee.org/colleges

Data from the American Society for Engineering Education (ASEE)¹⁰, reveal that biomedical engineering is the 8th top major for undergraduate students in engineering colleges

Forbes ranked BME as the #1 major that was worth student's tuition, time, and effort

“These aren't majors that anyone could do. They're hard, ...there is high demand for them and a low supply of people with the skills, so it drives up the labor market price.”

Goudreau, J. (2012, May 15). The 15 Most Valuable College Majors

Schools.com projects the career outlook for biomedical engineers in Virginia at 95.9%

Bachelor of Science Degree in Biomedical Engineering



Recent Graduate

Engineers and scientists develop new technologies that offer diverse technical and exciting career service, and test

Functional

Depending on b

- Biomedical
- Computer
- Electrical
- Materials
- Mechanical

Candidate

We're looking for technology comp

Candidates must

- Minimum
- A bachelor's degree in Science, Engineering, or
- Relevant



Patent Examiner (Biomedical Engineer)

Department Of Commerce 3.9 [96 Reviews](#) – Alexandria, VA

[Apply on Partner Site](#)

☐ Save

Job Description

About the Agency

Applications will also be accepted from students who expect to complete qualifying education within 9 months from the date of application. USPTO requires verification of successful completion before extending a final offer.

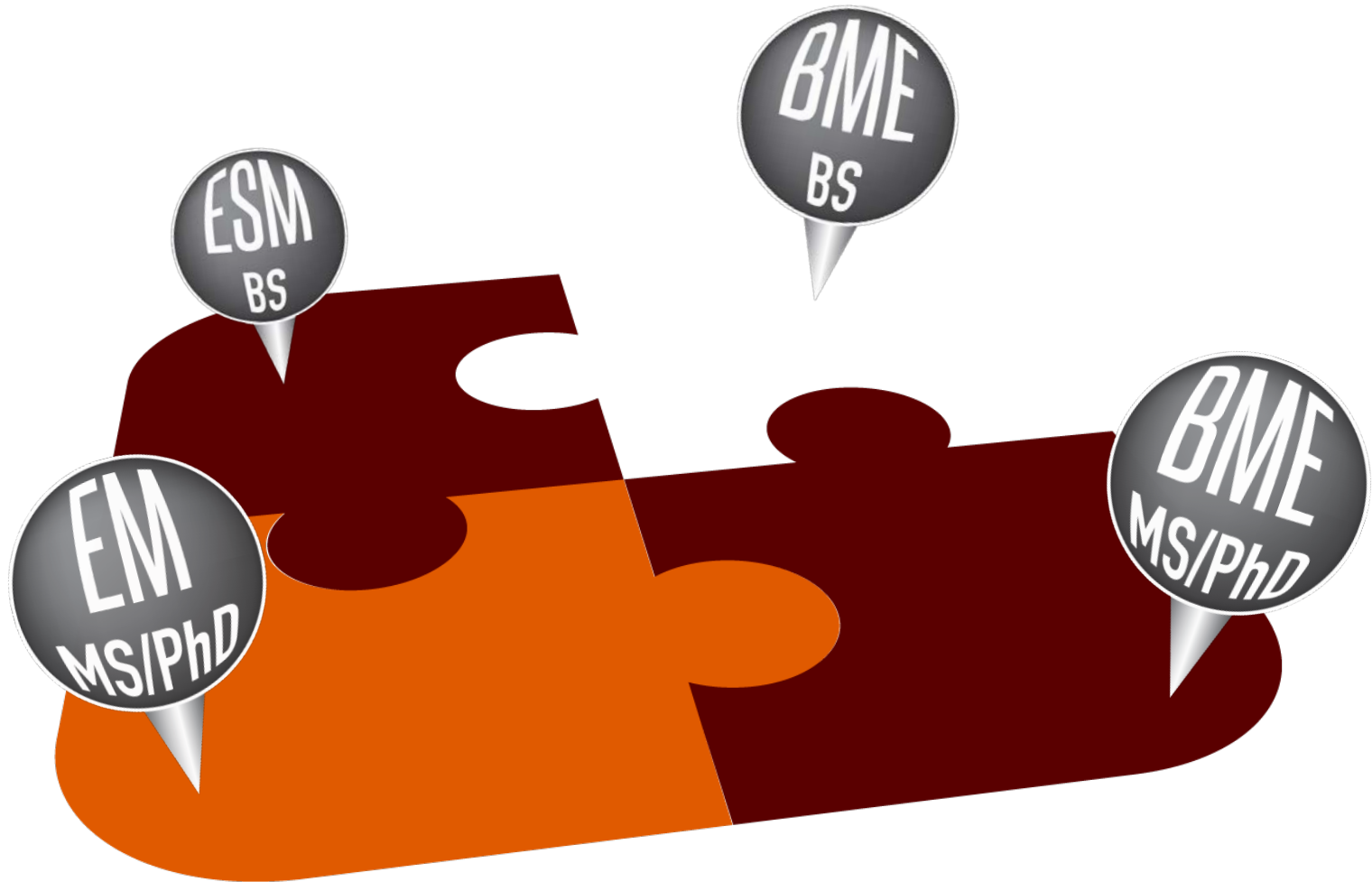
Come work for the USPTO, we have been ranked as one of the Best Places to Work in the Federal Government®!

The U.S. Patent and Trademark Office (USPTO) has been serving the economic interests of America for more than 200 years. We are responsible for granting US intellectual property rights for patents and trademarks. Our efforts have provided inventors exclusive rights over their discoveries. It's an effort that continues to contribute to a strong global economy, to encourage investment in innovation and to cultivate an entrepreneurial spirit for the 21st century. The USPTO is headquartered in Alexandria, Virginia, and has over 12,000 employees, including engineers, scientists, attorneys, analysts, IT specialists, etc. all dedicated to accomplishing the USPTO's mission, vision, strategic goals and guiding principles. For more information about the USPTO, please visit the USPTO Careers Website.

THIS VACANCY ANNOUNCEMENT IS FOR POSITIONS LOCATED IN ALEXANDRIA, VA ONLY. YOUR APPLICATION TO THIS VACANCY ANNOUNCEMENT WILL ONLY ALLOW CONSIDERATION FOR THIS ANNOUNCEMENT AND THIS DUTY STATION.

Please read this entire announcement before submitting application materials.

- Support project teams.



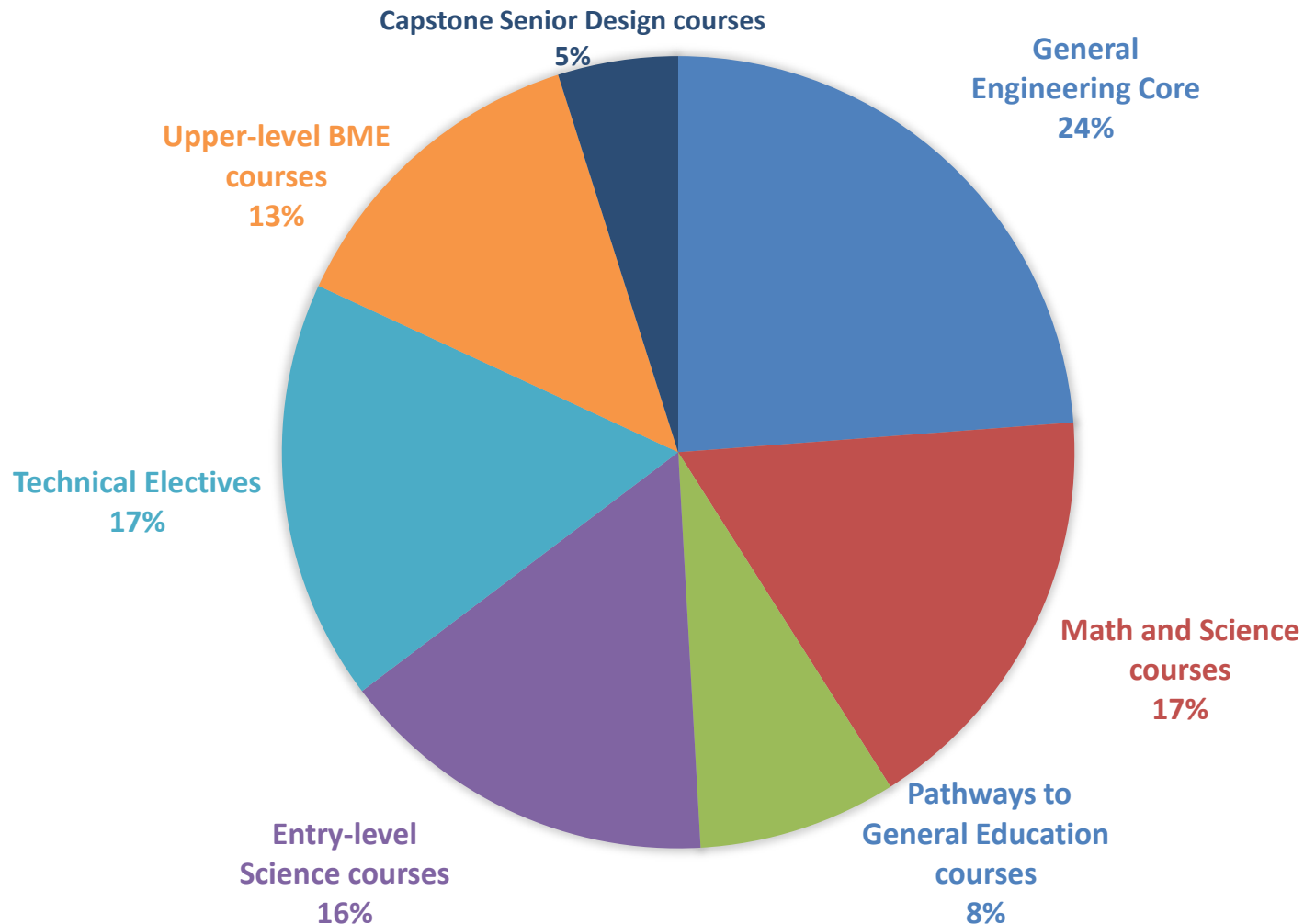
Department of Biomedical Engineering and Mechanics (BEAM)

Program Objectives

- **Educate and train the future biomedical engineers** for a complex, diverse and global workplace
- **Expose students to and provide opportunities for them to conduct state-of-the-art research** that embraces societal challenges
- **Capitalize on the department's biomedical partnerships with:** VT Carilion School of Medicine and Research Institute, Institute for Critical Technology and Sciences, Virginia-Maryland College of Veterinary Medicine, VT Biocomplexity Institute, VT Transportation Institute, and Edward Via College of Osteopathic Medicine (VCOM)
- **Establish the BEAM as the national leader in biomedical engineering education!**

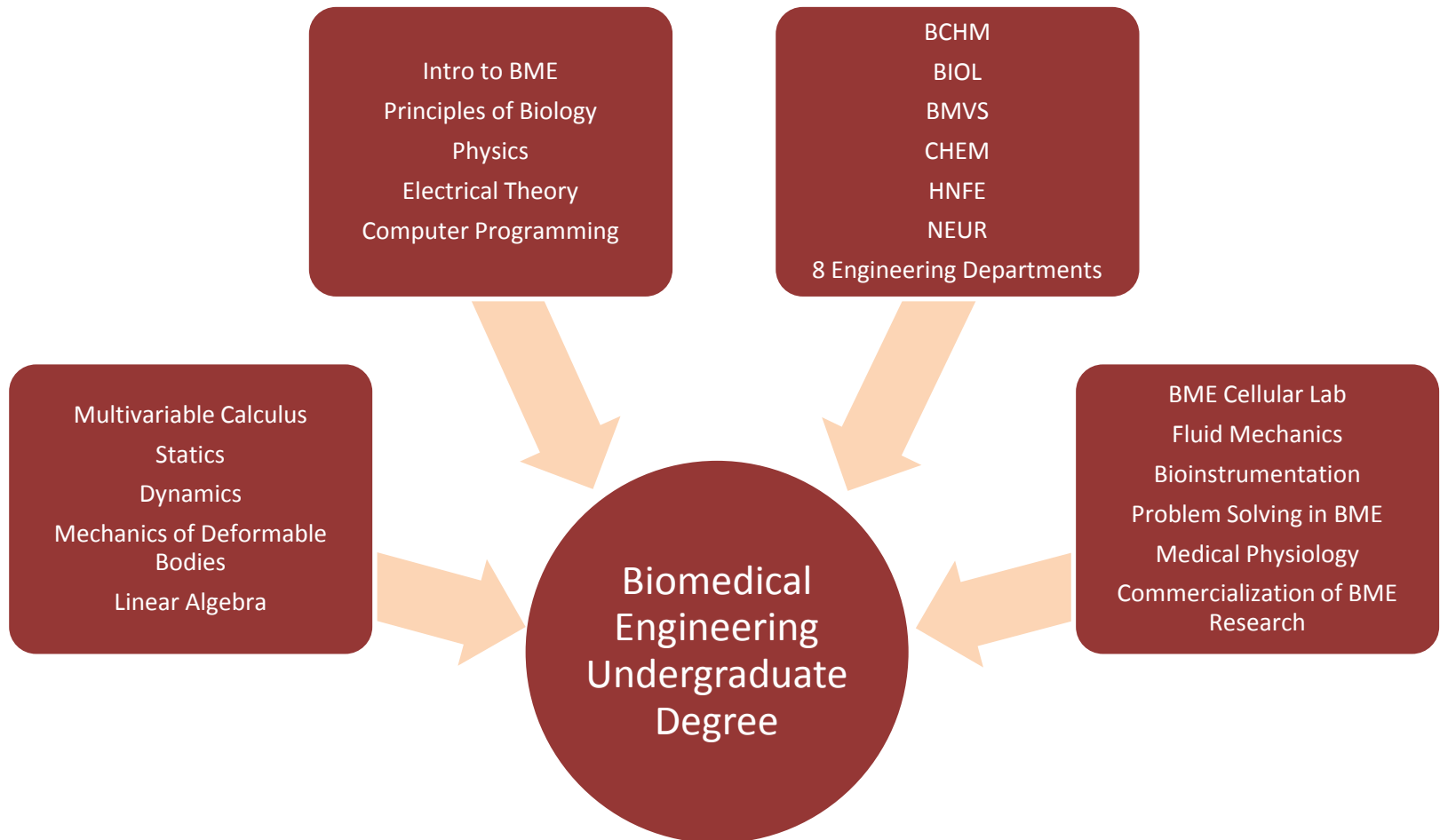
Bachelor of Science Degree in Biomedical Engineering

BME Curriculum Summary



Bachelor of Science Degree in Biomedical Engineering

Interdisciplinary Coursework



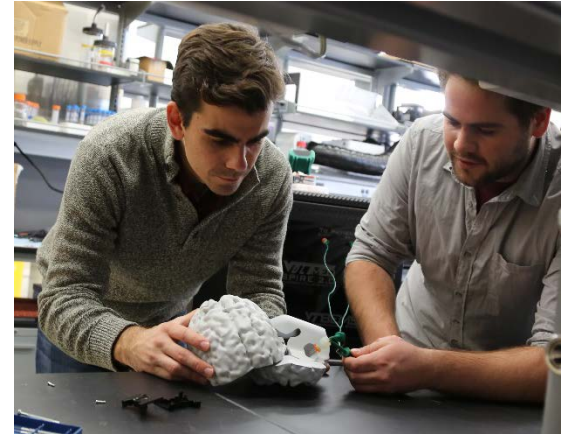
Why VT?

- Limited opportunity in Virginia, as only 2 other universities in the State have a bachelor's-level research-based education program
- VT 2012-2018 Strategic Plan proposes major growth in the fields of "science, technology, engineering, mathematics, and health sciences (STEM-H)"
- President Sand's emphasizes interdisciplinary programs and research opportunities
- Roanoke Health Sciences & Technology campus

Bachelor of Science Degree in Biomedical Engineering



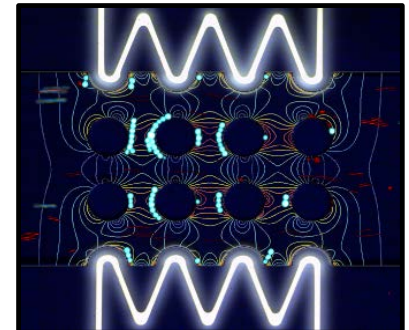
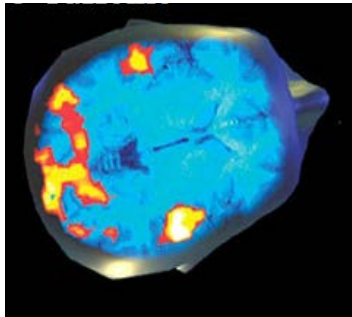
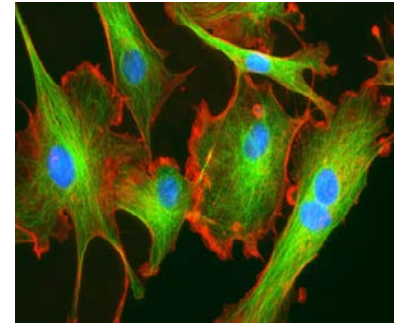
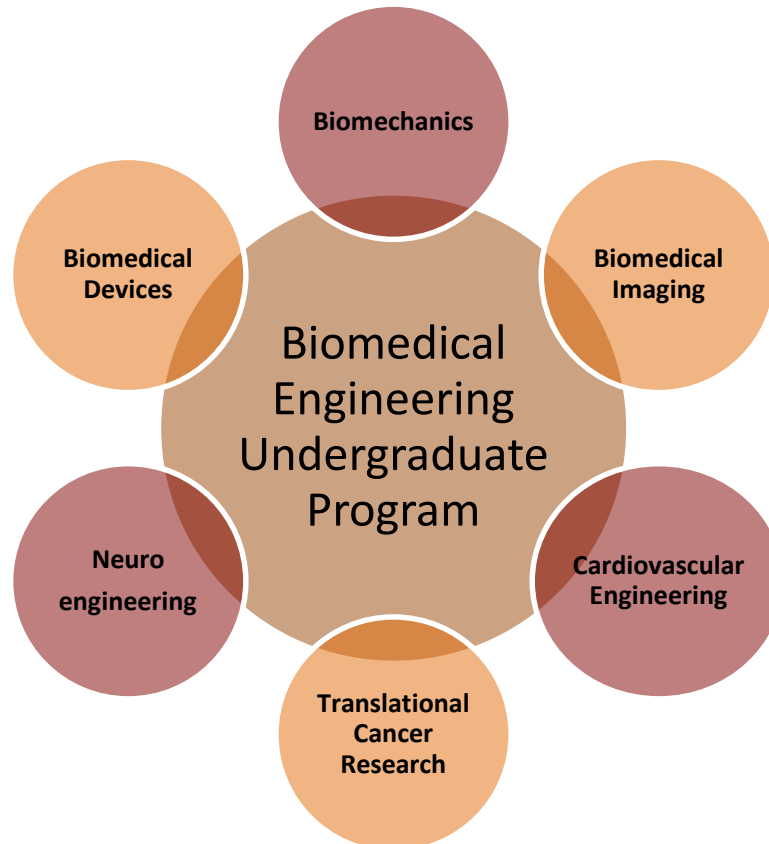
Why VT?



- VT BME Minor Program currently has over 200 undergraduates students enrolled
- Key participants in Destination Areas (Brain Behavior and Data Analytics)
- Draws on strengths of engineering faculty with expertise in biomedical research

Bachelor of Science Degree in Biomedical Engineering

VT College of Engineering has expertise in key
BME Research Areas



RECOMMENDATION:

That the above resolution recommending the establishment of the Bachelor of Science Degree in Biomedical Engineering be approved.

April 3, 2017