DRAFT PROPOSAL FOR NEW DOCTORAL PROGRAM

University of Louisville (School of Interdisciplinary and Graduate Studies)

Institution Submitting Proposal

Doctor of Philosophy in Interdisciplinary Studies with Specialization in Translational Bioengineering

Degree Designation as on Diploma

Doctoral Program in Interdisciplinary Studies: Specialization in Translational Bioengineering

Title of Proposed Degree Program

EEO Status _____

CIP Code 14.0501

Academic Unit (e.g. Department, Division, School) **School of Interdisciplinary and Graduate Studies**

Name of Academic Unit **School of Interdisciplinary and Graduate Studies**

Name of Program Director **Gina Bertocci, PhD, PE (co-director)**

Robert S Keynton, PhD (co-director)

Intended Date of Implementation **Jan, 2016**

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Date of Governing Board Approval _____

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Date of CPE Approval _____

Doctoral Program in Interdisciplinary Studies with Specialization in Translational Bioengineering

A. Centrality to the Institution's Mission and Consistency with State's Goals

1. Background

As part of former Governor Paul Patton's higher education initiative in 1998, the University of Louisville began the *Challenge for Excellence* to expand and enhance research in order to "become a premier, nationally-recognized metropolitan research university." In addition, local businesses commissioned consultants to recommend the means to improve competitiveness and they found that the local infrastructure is in place for Louisville to be competitive in the biomedical and biotechnology industries. In response to these initiatives, the University of Louisville, and in particular the Speed School of Engineering and the School of Medicine has made bioengineering its first priority and has demonstrated its commitment to developing a nationally recognized translational bioengineering program and to provide a formal structure for educating students in bioengineering and attracting faculty with the ability to establish multidisciplinary research programs with faculty on both the Belknap and the Health Sciences campuses. Existing faculty expertise have active research programs in a variety of areas including: biocomputational modeling, biofluids, bioimaging, bioinstrumentation, biomaterials, biomechanics, biomedical devices, BioMEMS, bionanotechnology, biosensors, biosignal processing, biosystems control, molecular bioengineering, and tissue engineering.

2. Program Objectives (Institutional and Societal)

The School of Interdisciplinary and Graduate Studies, partnership with the Speed School of Engineering, the Schools of Medicine and Dentistry and College of Business at the University of Louisville propose to establish a Doctoral Program in Interdisciplinary Studies with Specialization in Translational Bioengineering (ISSTBE). The proposed Ph.D. program has been designed to promote the University's research mission without duplication of existing programs either at the University of Louisville or at other state-assisted universities. The areas of expertise and successful track record of the faculty in securing extramural funding and publications in high-impact journals are concentrated in research and development (R&D) of diagnostic and therapeutic medical devices and interventions as well as basic research to understand the physical mechanisms involved in disease processes. As a result, the program will have a high probability for sustained productivity and closely aligns with the University of Louisville Challenge for Excellence. The ISSTBE program will enable students to pursue one of three tracks:

1) traditional bioengineering research,
2) clinical translational research, or
3) advancing bioengineering technologies through entrepreneurship.

The proposed program objectives are to:

1) train highly motivated graduate students with focus on clinical research as part of a multidisciplinary team in a fast-paced, interdisciplinary research environment; and,
2) develop students with the bioengineering expertise and practical experience to lead research and development of clinical translational technology as independent investigators in academia, industry, and government and/or advance bioengineering technologies through start-up companies.

Bioengineering is a relatively new engineering discipline when compared to the long-standing traditions of other fields of engineering. A bioengineer uses traditional engineering skills and tools to analyze and solve problems in biology and medicine. Bioengineers collaborate with physicians, biologists, biochemists, chemists, clinicians, dentists, physiologists, therapists, and virologists to design, develop and manufacture instruments, devices, materials, prophylactics, software, and therapeutics, or to develop new procedures to solve clinical problems. Bioengineers also are trained to objectively evaluate the efficacy of therapeutic interventions intended to advance healthcare and/or improve quality of life. The aging of the population and the focus on health issues will increase the demand for improved medical devices, equipment and therapeutics designed by bioengineers working on interdisciplinary teams. Employment opportunities for bioengineers are predicted to continue growing faster than the average for all occupations through 2020 as reported by CNN Money [1] with a 10-year job growth of ~62%. Combined with a growing job market and attractive compensation (median pay: $87,000[1]), bioengineers have the gratification that comes from working to meet the needs of society. Bioengineers choose their field to be of service to people and animals, to be a part of the excitement of working with living systems, and to apply advanced technology to the complex problems biological systems and healthcare.

With regards to societal impact, premature death rate is a surrogate indicator for overall health status, with high rates suggestive of decreased work productivity and economic development. Unfortunately, the premature death rate in Kentucky exceeds the national average.[2] Closer evaluation reveals that Kentucky has a higher incidence of cancer, heart disease, diabetes, high blood pressure, asthma, disabilities and periodontal disease than most states.[3] Cancer, cardiovascular disease and respiratory illness are often consequences of tobacco use. More than half of individuals who smoke will die of a smoking-related illness. Coincidentally, 23% of all deaths in Kentucky can be attributed to smoking. Death rates associated with lung, colorectal, prostate and breast cancer in Kentucky greatly exceed national averages. Another major health challenge facing Kentuckians is obesity, which leads to an increased incidence of cardiovascular disease, diabetes, stroke and other health disorders. Violence-related fatalities also plague our Commonwealth, with Kentucky having the dubious distinction of one of the highest rates of child maltreatment, exceeded only by New York and the District of Columbia. Accidental injuries, such as those resulting from motor vehicle crashes, are also a leading cause of death in Kentucky. Advancing the health status and providing safe environments for Kentuckians is key to improving the productivity and economic viability of our Commonwealth. Advanced level bioengineers, working in collaboration with clinical scientists and clinicians, are uniquely positioned to influence change through the development and translation of early diagnostic and interventional biomedical devices and technologies. Additionally, through the application of advanced engineering principles and techniques, bioengineers work in multidisciplinary teams towards the discovery of underlying disease etiologies allowing for the development of therapeutic strategies to limit or mitigate morbidity and improve quality of life. Currently U of L bioengineering faculty, students and trainees are collaborating with their clinical counterparts to address many of these daunting health-related problems (e.g. cancer, child maltreatment, cardiovascular disease, disabilities, diabetes, motor vehicle related injuries) challenging Kentuckians. However, creating a sustainable positive impact on the health and well being of Kentuckians is dependent upon effective capacity building in the field of bioengineering. The proposed ISSTBE PhD program presents a unique multidisciplinary opportunity to train students to become advanced-level researchers and entrepreneurs who will have the

[1] http://money.cnn.com/gallery/pf/jobs/2013/11/13/fastest-growing-jobs/
[2] State Health Assessment, KY Dept. for Public Health, 2013
[3] The Health of KY, KY Institute of Medicine, 2007

capabilities to influence the health and quality of life of Kentuckians and those living with similar morbidities. Students matriculating from this Program will have a unique skill set and the potential to lead multidisciplinary teams in the design, development and translation of solutions and technologies to advance the health status of Kentuckians, thereby aiding our Commonwealth in realizing improved productivity and economic gains.

3. Institutional Mission and Academic Plan

The mission of The University of Louisville is to be a premier, nationally recognized metropolitan research university with a commitment to the liberal arts and sciences and to the intellectual, cultural, and economic development of our diverse communities and citizens through the pursuit of excellence in five interrelated strategic areas: 1) Educational Experience; 2) Research, Creative and Scholarly Activity; 3) Accessibility, Diversity, Equity and Communication; 4) Partnerships and Collaborations; and, 5) Institutional Effectiveness of Programs and Services. The mission of the J. B. Speed School of Engineering is to serve the university, the Commonwealth of Kentucky, and the engineering profession by providing high quality educational programs to all students engaging in research and scholarship that will extend knowledge and assist the economic development of the regional, state, and national economies through technology transfer. The mission of the School of Interdisciplinary and Graduate Studies, in collaboration with the academic units mentioned above, is to provide students with an excellent education through coursework, research and co-operative work experience to enable successful, innovative, and life-long careers in STEM/Health fields. Graduates of the proposed program will have a mastery of underlying translational bioengineering sciences and related technologies, as well as professional, ethical, and societal responsibilities.

Our request is in response to the University of Louisville's Office of the Provost academic plan and Office of the Executive Vice President for Research & Innovation strategic plan to develop a highly competitive doctoral graduate program in bioengineering to meet the University's, Community's, and State of Kentucky's needs for growing engineering technical, research, and translational competency as well as supporting clinical and entrepreneurial translational research needs of the Engineering, Medical, Dental, and Business Schools. Specifically, our PhD program meets the 2020 Strategic Plan goals for "developing novel niche and interdisciplinary research foci", "to develop new interdisciplinary programs", "to achieve strategic goals that are interdisciplinary or that cannot be accomplished by the core school/department structure", and "promote interdisciplinary research and educational programming."

4. State's Post-Secondary Education Strategic Agenda

The Doctoral Program in Interdisciplinary Studies with Specialization in Translational Bioengineering is in alignment with the State of Kentucky's *Stronger by Degrees*[4] post-secondary education strategic agenda. It aligns with the agenda by providing a vehicle to enable all Kentuckians to succeed in a global economy (Vision), delivering a world-class education to our students through the creation and application of new knowledge, and growing the economy of the Commonweath (Mission). Specifically, our program will:

1) foster cooperation and teamwork;
2) stimulate fiscal and intellectual stewardship;
3) create innovative approaches for medical diagnostics and therapeutics, including technology to meet the clinical and economic needs of the Commonwealth;
4) engage industry and community partners to improve economic vitality and quality of life; and,

[4] http://cpe.ky.gov/NR/rdonlyres/0BA94290-AAF3-452D-AB5F-5F0EF73523C7/0/strategicagendafaqs.pdf

5) promote graduate education in the field of bioengineering in partnership with clinician-scientists to improve patient outcomes and quality of life, especially in clinical areas of high importance to the State of Kentucky, in particular, cardiovascular, cancer and neurosciences.

Consistent with the vision of Robert King, President, Council on Post-Secondary Education, this program will lead to the creation, research and development, and clinical and entrepreneurial translation of new knowledge to improve the human condition and strengthen Kentucky's economy.

The proposed program fulfills the *Research, Economic, and Community Development* criteria - Kentucky will be stronger by generating new knowledge and research investments, producing high-demand degrees, increasing the educational attainment of its workforce, and improving its communities. Specifically, engineering, clinical, and business faculty and students will meet critical needs to increase basic, applied, and translational research to create new knowledge and economic growth[2] (Strategic Policy Objective 7). This program will also increase educational attainment and quality of life in Kentucky communities through regional stewardship[2] (Strategic Policy Objective 8). Additionally, by addressing the need for Efficiency and Innovation, Kentucky will be stronger by creating new ways of serving more postsecondary students at a high quality in a challenging resource environment by increasing academic productivity through innovation[2] (Strategic Policy Objective 9) and maximizing postsecondary and adult education resources[2] (Strategic Policy Objective 10).

5. Statewide Implementation Plan

The proposed Doctoral Program in Interdiscplinary Studies with Specialization in Bioengineering addresses the State's postsecondary education and strategic agenda implementation plan. Specifically, *Adequate Funding* to support graduate student education (tuition and stipend) will be provided by collaborative relationships involving engineering, clinical, and business faculty in securing federal grants, private foundation grants, industry contracts and the School of Interdisciplinary and Graduate Studies. Additionally, multidisciplinary teams, focused on clinical areas of high need, will pursue federally funded training grants to support graduate students in the ISSTBE program. The Bioengineering Department has a proven track record of *Accountability* in higher education as demonstrated by ABET accreditation of the BS and MEng degrees (July 1, 2013); the only jointly accredited program in the nation, which was achieved using well-defined *Performance Metrics and Targets*, an *Implementation Plan*, and annual *Reporting and Benchmarking*. Our engineering, clinical, and business faculty have demonstrated a nationally and internationally-recognized level of research productivity as evidenced by quality and placement of our graduate BS and MEng students, presentations at national and international conferences, publications in high-impact peer refereed journals, and extramural funding. The success of existing faculty will enable the delivery of high quality educational and research opportunities for students, and will lead to graduates capable of translating their knowledge through innovations and the creation of entrepreneurial ventures to address the clinical needs of Kentuckians and society. In summary, the proposed ISSTBE Doctoral Program at the University of Louisville will exceed the requirements of our State's Strategic Agenda.

B. Program Quality and Student Success

1. Student Learning Outcomes

Students who successfully complete the ISSTBE doctoral program will have achieved the following Student Learning Outcomes:

a) demonstrated excellence in their ability to design and conduct original research leading to a unique intellectual contribution to the field;

b) demonstrated in-depth knowledge of their chosen bioengineering concentration area (listed below) and associated scientific literature:
   i. Bioelectronics and Biomedical Devices,
   ii. Bioimaging and Biocomputational Modeling,
   iii. Biomechanics and Rehabilitation, or
   iv. Molecular and Tissue Engineering;
c) an understanding of the clinical relevance and ethical implications of their research;
d) the ability to critically analyze, evaluate and interpret research methods and findings;
e) the ability to effectively communicate knowledge of their concentration area and research orally and in writing.

Since this doctoral program has not been established yet, these student learning outcomes have not been assessed or evaluated to date. However, a description of the assessment and evaluation process that will be implemented are described below in Section E.

2. How the Curriculum Achieves Student Learning Outcomes

This program conveys the Institution's commitment to provide students with high quality educational experiences and the advancement of research, scholarship, and innovation for creating partnerships and stimulating economic development. Program objectives established for the PhD ISSTBE program are consistent with the mission of the University. The program will produce high quality doctoral engineering graduates who will: 1) lead successful and productive careers to advance our society's health and well being; 2) be able to work together and effectively communicate their ideas to colleagues and stakeholders with diverse backgrounds; and, 3) recognize the need for lifelong learning to grow professionally. Successful ISSTBE doctoral graduates will have the capacity to serve as independent investigators on multidisciplinary teams leading our scientific community in creating and developing technologies and conducting research that directly advances quality of life, while making healthcare technologies more widely available.

The major PhD ISSTBE curriculum components include didactic coursework (core, track, and specialization courses), a clinical practicum or teaching practicum (dependent upon chosen track), and dissertation research. Students will be assigned an advisor upon entry to the program to guide them through the initial phase of the program, including provisions for an overview of program options (i.e. tracks and concentration areas), required core courses per track and concentration area courses, and preparation for the Qualifying Exam. Students entering the program with a pre-chosen track and concentration area will be assigned a faculty advisor with expertise in their chosen track and concentration area. A passing grade on the Qualifying Exam will assure that students have attained core competencies at an advanced bioengineering level with a depth of knowledge in their track and concentration area, as well as competency in research design and ethics. The Bioengineering Seminar (BE 601) series will expose students to a range of research topics within the field of bioengineering, and will aid students in choosing a track, concentration and specialization. After successfully completing the first semester of the program, students will identify a Dissertation Chair in their track and area of concentration who will serve as their primary advisor for the remainder of their PhD program. They will work with their Dissertation Chair to identify a dissertation topic and appropriate specialization courses. The student and Dissertation Chair will develop a Plan of Study mapping specialization courses that the student will complete to obtain engineering, clinical and entrepreneurial education and experiences (dependent upon their chosen track) necessary to support their dissertation research and enabling them to become an expert in their field of specialization. Additionally, the student will work with their Dissertation Chair to identify Dissertation Committee members to assure that the student will have a robust representation of expertise

needed to guide their dissertation process. Through their dissertation research they will learn and demonstrate their ability to achieve the Student Learning Outcomes listed above. Teaching and clinical rotation practicums will further their capacity to effectively communicate their bioengineering knowledge to a diverse audience. Student progress will be reported to and reviewed by the Executive Committee each year.

3. Distinctive Qualities

Since this proposal seeks to establish a new degree program, the ISSTBE program and students have not achieved external recognition to date. However, the students and faculty as well as the Department of Bioengineering, School of Medicine, School of Dentistry and College of Business at the University of Louisville (U of L) have received several prestigious honors and awards over the past five years. Specifically, in 2010, the Wallace H. Coulter Foundation selected the U of L Department of Bioengineering in collaboration with the U of L School of Medicine and Office of Technology Transfer to join the $5M Coulter Translational Partnership program to establish a translational research program. This prestigious award placed the University of Louisville in the "Sweet 16" of US Institutions in the area of Translational Research along with: Boston University, Case Western University, Columbia, Drexel, Duke, Georgia Tech, Johns Hopkins, Stanford, University of Michigan, University of Missouri, University of Pittsburgh, University of Southern California, University of Virginia, University of Washington and University of Wisconsin. The proposed Doctoral Program in Interdiscplinary Studies with Specialization in Translational Bioengineering will leverage the Coulter Translational Partnership Award to accelerate the development and growth of clinical translational research at the University of Louisville. The mission of the Coulter Translational Partnership (CTP) in Bioengineering at the University of Louisville is to promote medical innovation by establishing critical collaborations between engineers and clinicians to address significant unmet clinical needs. The Coulter Translational Partnership provides seed funding (~$100k) for promising projects to accelerate the translation of innovations to clinical practice by providing a roadmap for commercialization of the University technology. This partnership is strongly milestone-driven and focuses on outcomes such as generation of new intellectual property, creation of start-up companies that successfully secure venture capital and angel investor funding, licensing of patents and improving diagnosis and treatment of disease.

The clinical translational research and development (R&D) and entrepreneurial mission embody our highly innovative and novel educational paradigm, which will place the University of Louisville at the forefront of bioengineering programs nationally. ISSTBE students will have the option to complete a Traditional Bioengineering Research, Clinical Translational Research or Advancing Bioengineering Technologies through Entrepreneurship track within their doctoral degree. Doctoral students will be provided unique and extraordinary learning opportunities that include a customizable curriculum, practical hands-on experience in a fast-paced environment, participation on multidisciplinary teams, and specialized training in clinical and entrepreneurial translational R&D. Engineering, Clinical, and Entrepreneurial faculty will mentor doctoral students leveraging our successful approach(s) to identifying clinical needs, designing research studies to address clinical questions, conducting research studies, and analyzing and interpreting findings in the context of the clinical need. Those students following a device development pathway will gain expertise in device design, developing proof-of-concept prototypes, evaluating prototype feasibility, conducting pre-clinical studies to evaluate device design in compliance with Good Laboratory Practices (GLP) for Food & Drug Administration (FDA) approval for clinical use, identifying regulatory pathway(s) and conducting clinical trials. They will also be provided instruction on developing competitive commercialization plans to secure venture capital or small business innovation research (SBIR) funding, building and leading multidisciplinary teams, creating 'start-up' company(s), entering into licensing agreement(s), and/or establishing medical device

industry partnership(s). Collectively, the Speed School of Engineering, Medical and Dental Schools, and College of Business have extensive experience and track records of successfully translating clinical and entrepreneurial ventures for the development of diagnostic and therapeutic technologies to improve patient outcomes and quality of life in the Commonwealth and Nationally. Thus, we are uniquely positioned to offer specialized training in clinical and entrepreneurial translational research to ISSTBE doctoral students to be future catalysts in building and growing the local knowledge-based, experience and expertise required to meet the unmet clinical needs (cardiovascular, oncology, and neurosciences) of our community. Our proposed PhD ISSTBE is unique to the Commonwealth providing students with opportunities to focus on Clinical Translational Research or Advancing Bioengineering Technologies through Entrepreneurship. We are aware of only two other PhD programs in Bioengineering in the US (University of Pennsylvania, University of Colorado-Denver) offering a Track that brings together the development of bioengineering technologies and entrepreneurship to promote commercialization of technologies to address clinical needs.

4. Replacement or Enhancement of Existing Programs or Concentrations

The proposed program will not replace any existing programs. However, it will expand upon our existing ABET accredited Bachelor of Science and Master of Engineering degree programs in bioengineering by offering a PhD in ISSTBE which will enable the Department of Bioengineering to deliver a comprehensive degree portfolio and provide new, exciting opportunities for Kentucky residents to reduce the "brain drain" of our state. Given the unique multidisciplinary nature of the proposed PhD ISSTBE, we also anticipate attracting students from outside the Commonwealth. The doctoral degree program will enable students to follow one of three tracks: 1) traditional bioengineering research; 2) clinical translational research; or, 3) advancing bioengineering technologies through entrepreneurship. This unique doctoral level bioengineering program is currently not available at any other institution in the state and one of only a three in the country.

5. Accrediting Agency

There is no accrediting agency for Doctoral Degrees in Translational Bioengineering; however, all doctoral programs at the University of Louisville are accredited by the Council on Postsecondary Education and the Southern Association of Colleges and Schools (SACS).

6. SACS Faculty Roster Form

The SACS Faculty Roster Form is included in Appendix A. All courses, both core and elective, with the exception of Advanced Research & Design Methods, Bioengineering Seminar, Research Ethics in Bioengineering, Teaching Practicum, and Medical or Dental Clinical Rotation, are currently being taught by faculty in participating departments who support the ISSTBE program. Bioengineering faculty biosketches are included in Appendix A. Letters of support from Chairs of departments indicating their willingness to have faculty provide didactic instruction and permit ISSTBE students to enroll in their courses are also included in Appendix A.

7. Library Resources, Physical Facilities, and Instruction Equipment

Library Resources - The ISSTBE will be supported by the Ekstrom (Main) and Kornhauser Libraries which house over 2.1 million volumes, approximately 16,000 current journal subscriptions, special collections, media and microforms. In addition, the library has an on-line virtual library that provides faculty, staff and students access to over 20,000 full text electronic journals, inter-library loan services, electronic books and databases, reference materials and other library resources. The library resources are more than adequate to support the needs of the faculty and students in the proposed ISSTBE doctoral program.

A letter from the Dean, University Libraries is included in Appendix B, indicating that the University's collection of journals, electronic resources and special collections is adequate to support the ISSTBE program.

Offices - The Bioengineering Department is located on the University of Louisville Belknap campus in Lutz Hall which contains the department office, two teaching classrooms, two instructional laboratories, a conference room, and faculty research laboratories. Offices for faculty and staff are located in buildings across the Belknap Campus (Lutz Hall and Shumaker Research Building) and Health Sciences Campus (Cardiovascular Innovation Institute, Clinical Translation Research Building and Health Sciences Research Tower). Offices for faculty and staff in the School of Business are located in Harry Frazier Hall on the Belknap campus. In addition, department and faculty offices for other Speed School of Engineering departments are located in Ernst Hall (Chemical Engineering), Duthie Center (Computer Engineering & Computer Science), J.B. Speed Building (Industrial Engineering), Sackett Hall (Mechanical Engineering), W.S. Speed Building (Electrical & Computer Engineering). Offices for faculty and staff on the Health Sciences Campus are located in Building A-Research Tower (Biochemistry & Molecular Biology; Microbiology & Immunology; Physiology & Biophysics), Medical & Dental Research Building (Anatomical Sciences & Neurobiology) and School of Dentistry.

Classrooms and Instructional Laboratories – The proposed bioengineering-specific courses are offered primarily in Lutz Hall, but the additional program courses are offered in classrooms across both the Belknap and Health Sciences Campuses including the Clinical Translational Research Building, Duthie Center, Ernst Hall, Harry Frazier Hall, HSC-A Building, HSC Instructional Building (B-Bldg.), HSC-K Building, J.B. Speed Building, Sackett Hall, School of Dentistry, and W.S. Speed Building for delivery of the proposed curriculum. All of the classrooms have adequate lighting, climate control and acoustic characteristics, and are equipped with computers that interface with overhead LCD projectors. All buildings on the Belknap and Health Sciences Campuses are equipped with wireless internet access.

Computing Resources - The University of Louisville central research-computing or Cardinal Research Cluster (CRC) is housed in the UofL Information Technology Data Center located in the Miller IT Center on the university's Belknap campus. This facility provides over 5000 square feet of secure, environmentally controlled data center space including a FM200 fire suppression system. The data center is fed by 1000kVA electrical service with backup power provided by a large UPS and an 1125 kVA diesel generator. The research cluster is equipped with its own dedicated in-row cooling systems, and utilizes cold aisle containment to improve cooling efficiency. The facility is physically secure with limited keycard access and is monitored 24 hours a day. The UofL CRC infrastructure became available in spring 2009 and was upgraded in spring 2011. This infrastructure includes multiple systems serving the research needs of the entire university, including a general-purpose high-performance distributed-memory computation cluster, a high-memory SMP system and several general-purpose web and software servers. The general-purpose compute cluster is composed of 312 IBM iDatplex nodes each equipped with two Intel Xeon L5420 2.5 GHz quad-core processors for a total of 2496 processor cores. Each node has 16 or 32 GB of memory, and the node interconnects are a mixture of Gigabit Ethernet (1Gbps) and InfiniBand (16 Gbps) technology. The cluster is estimated to have a peak performance rating of 20+ TFLOPS. The University of Louisville's campuses are served by a 40 Gigabit per second (Gpbs) campus backbone network. This backbone is comprised of over 80 miles of fiber in a dual ring configuration. The wired network can provide 100Mbps and 1Gbps Ethernet service for faculty and staff communications needs. With the recently completed Pervasive Wireless Project, the U of L campus wireless network provides 802.11n wireless connectivity to wireless devices at speeds up to 300Mbps. This wireless connectivity is available across all of U of L's campuses, classrooms and buildings. The University of Louisville is connected to the Internet2 node via dedicated 10Gbps optical fiber backbone network. The Internet2

connection gives the University of Louisville direct, high-bandwidth, access to national research and education networks such as XSEDE/Teragrid. The University of Louisville is also a member of the Kentucky Regional Optical Network (KyRON). This regional optical network is managed and operated through a consortium including the University of Louisville, the University of Kentucky and the Kentucky Council on Postsecondary Education. Participating universities are interconnected using 10Gbps optical links. The Kentucky RON extends the research data sharing capabilities of the University of Louisville with other participating universities throughout the state, and provides new opportunities for collaboration.

Multi-Disciplinary & Core Research Facilities - To support the training of students in state-of-the-art research methodologies and techniques, all ISSTBE students will have access to a number of multidisciplinary and core research facilities (described below) as well as individual investigator laboratories (described in Appendix B). Specifically, students will have access to the multiuser facilities described below:

BIOINFORMATICS LABORATORY is housed in the CECS department in room 238 of the Duthie Center. The facilities include a: visualization wall consisting of an assembly of 3x6 Dell monitors and used to visualize complex images; video conferencing system; powerful computers including Dell precision T7400 (8 processors, 20 gb RAM, 2 TB HDD, NVIDIA card) and Dell Alienware computers (8 processors, 12 GB RAM, 1 TB HDD, NVIDIA card); library with bioinformatics and related fields books; and, panaboard (Panasonic White board) that can take pictures of the discussion and can be saved and printed from computer.

CONN CENTER MATERIALS CHARACTERIZATION FACILITY: Electron Microscopy including High Resolution FEG-TEM/STEM, High Resolution FEG-SEM, and Analytical SEM. The instruments in the Conn Center Materials Characterization Facility include a 200-kV field-emission FEI Tecnai F20 TEM, a field-emission FEI Nova600 SEM, and an analytical JEOL JMS5010 SEM. TEM accessories consist of Gatan GIF2002 and EDAX spectrometers, a Fishione HAADF detector, and various sample holders (3-D tomography, cooling, heating, etc.). The system is capable of high-resolution (HRTEM), energy-filtered (EFTEM) and Z-contrast (STEM) imaging, diffraction (SAED, CBED, nanodiffrcation), analytical and spectroscopic studies (EELS, EDX, chemical tomography) at nanoscale, as well as, in situ heating (up to 1100 oC) and cooling (down to LN2 temperature) experiments. The imaging point resolution of 0.24 nm and spectroscopic energy resolution of 0.8eV can be obtained with this system.

THE UNIVERSITY OF LOUISVILLE MICRO/NANOTECHNOLOGY CENTER occupies approximately 12,000 sq ft and includes laboratories focused on the development of MEMS/NEMS-based devices using: 1) Computer-aided design; 2) testing and packaging; 3) microfabrication cleanroom; and, 4) micromechanical machining. The UofL Micro/NanoTechnology Center conducts and facilitates R&D on MEMS/NEMS-based technologies including those with high commercialization potential. The Center promotes partnerships among the state's colleges and universities, private industries, and non-profit organizations to actively pursue federally and privately funded research and development resources that are dedicated to MEMS/NEMS solutions

MICRO/NANOTECHNOLOGY CLEANROOM - FACILITY. The Micro/NanoTechnology Cleanroom (MNTC) is a $30M class 100/1000 cleanroom facility established to support a wide range of research and academic initiatives in the growing areas of micro/nanotechnology, advanced materials, biotechnology, MEMS at the University of Louisville and throughout the state of Kentucky. This 10,000 ft^2 Abbie Gregg, Inc. designed cleanroom opened in the Summer of 2006 and is located on the 1st floor of the new $60M Shumaker Research Building. The cleanroom is strategically divided into 7 bays – two for photolithograghy and mask generation, one for wet processing (etching/cleaning/plating), one for dry etching, one for thin film deposition, one for

high temperature processing, and one for PDMS processing. The Micro/NanoTechnology Core Facility is utilized for the fabrication of MEMS (microelectromechanical) devices and structures, bioMEMS devices, nano-scale devices and structures, microelectronic devices, and electro-optic devices. It is utilized by a wide variety of disciplines, including ECE, ME, BE, ChE, Chemistry, Physics and Medicine. Due to stringent processing requirements, the lab is designed to meet class 1000 cleanroom specifications within five of the processing bays and class 100 specifications in its two lithography bays. Activities performed in the MNTC Cleanroom include: photolithography with back side alignment, e-beam lithography, oxidation, thermal diffusion and annealing, rapid thermal processing, thermal and electron beam evaporation, plasma enhanced chemical vapor deposition (PECVD), Molecular Vapor Deposition (MVD), Atomic Layer Deposition (ALD), RF/DC sputtering, spinning, parylene deposition, RCA substrate cleaning, anisotropic and isotropic dry and wet etching, XeF2 isotropic dry etching reactive ion etching (RIE), deep reactive ion etching (DRIE), bulk micromachining, anodic bonding with wafer bond alignment, silicon fusion bonding (SFB), low temperature glass bonding, electroplating, photomask generation with greyscale capabilities, maskless lithography or direct write, wirebonding, metrology and material characterization.

MEMS COMPUTER-AIDED DESIGN LABORATORY - FACILITY includes four high end workstations located in the Belknap Research Building are dedicated to running CoventorWare© a MEMS finite element modeling software which has modules for simulation of mechanical, electrical, thermal, and fluidic phenomenon in the micro regime. Both pre-processing (model design and generation) and post-processing (simulation and data extraction) is accomplished on the workstations. The workstations are also equipped with L-EDIT, Athena and T-Spice software for MEMS layout generation, semiconductor fabrication process simulation and circuit modeling, respectively. In addition, the licensing configuration for the software effectively allows anyone on campus to run the software, which is particularly advantageous for inspecting results at locations away from the more powerful systems.

MEMS TESTING & PACKAGING LABORATORY – FACILITY is a 1200 sq. ft. laboratory for the packaging and testing of MEMS devices fabricated in the Micro/Nanotechnology Facility. The lab includes two fume hoods and a full complement of utilities, including DI water. This research and instructional facility contains numerous backend and post-processing pieces of equipment appropriate for the packaging and assembly of MEMS and microelectronic devices. Additionally it contains many electronic instruments for device testing and characterization.

MICROMECHANICAL MACHINING LABORATORY - FACILITY is dedicated to the development of micro mechanical machining methodologies to produce MEMS-based devices fabricated out of non-silicon materials as well as silicon. The lab includes a full complement of utilities including nitrogen, air, water, a sink, and electrical outlets. This facility contains multiple pieces micromechanical machining equipment.

HUSON NANOTECHNOLOGY CORE FACILITY: This analytical imaging facility was established in 1998 with the partial support of an NSF MRI grant. It is housed in the new Belknap Research Building which opened in December 2005 and consists of ~1800 sq. ft. of space which contains microscopes that can measure the three-dimensional shapes of ultrasmall objects with precision up to 5000X finer than that of conventional light microscopes. The Three-Dimensional Nanoscale Imaging Facility features several complementary instruments that can measure three-dimensional topography and other related physical properties of nanoscale and atomic surfaces. These instruments are the first of their kind at a Kentucky university or business. All instruments are PC controlled and attached via TCP/IP to a local Microsoft Windows NT domain, and the university's main network. The 3D Nanoscale Imaging Facility is actively used by various research groups for

diverse projects that require ultra-precise three-dimensional profiling, and even nanoscale-sculpting of small surfaces.

INSTITUTE FOR PRODUCT REALIZATION (IPR) is a new institute that consists of three basic units: 1) Manufacturing Pilot and Launch Pad; 2) Microfactory and Co-Creation; and 3) Technical Research. An anchor component of the Manufacturing Pilot is the Rapid Prototyping Center, which is a well established center dating back to the early 1990's. All other components of the IPR are currently in the construction or planning stages. In particular, renovation of UofL space for the Microfactory began in April 2014 and opened in Fall 2014. The Microfactory and Co-Creation facility are open and functioning.

RAPID PROTOTYPING CENTER – FACILITY: The University of Louisville (UofL) has one of the best equipped facilities with world class capabilities for 3D Printing/Additive Manufacturing (AM) of metals and polymers. The industrial/academic consortium known as the Rapid Prototyping Center (RPC) has been performing federally-funded basic and applied research, technology transfer and industry-funded projects in AM since starting with polymer Laser Sintering (LS) in 1993. Today the UofL has over 20 people focused on AM applications and research. The UofL is a partner of leading AM users such as Boeing, GE, EWI, Nike, Emerson, Northrop-Grumman, Burton, Integra, and several service bureaus. There are over 70 industrial/academic consortium member organizations in the Rapid Prototyping Center. The University of Louisville Rapid Prototyping Center (RPC) was formed in 1993 as a consortium between the university and five local companies to investigate the new technology of rapid prototyping via laser sintering and its impact on the design cycle. Today the RPC's 70+ members have access to world-leading capabilities in Additive Manufacturing (AM) via laser and electron beam powder bed processes for metals, plastics, and ceramics; ultrasonic additive sheet lamination; plus many ancillary processes and techniques. The assistance available to joint academic/industrial consortium partners has grown from helping companies to understand rapid prototyping to aiding members in the entire product development process: conceptual design, material selection, prototyping, tooling, production, applied and basic research. The RPC has the latest software for solid modeling and part design of new components and the capability for reverse engineering of existing parts. The RPC combines the expertise of its professional staff and faculty with strategic partnerships to assist in all aspects of product and process development. The RPC supports research and development programs in Additive Manufacturing and provides student instruction in the application of these new technologies. The role of technology transfer and new business development is fueled by interaction with the industrial consortium members and emphasizes the utilization of University resources to enhance job growth. Users gain access to the problem-solving technology as well as continuing research in Additive Manufacturing. Benefits also include access to UofL's Speed School of Engineering graduates- engineers of the future with training in this state of the art technology. The University of Louisville Rapid Prototyping Center (RPC) is capable of producing prototypes and end use, low volume component parts utilizing the following additive manufacturing systems: Laser Sintering (LS), Direct Metal Laser Sintering (DMLS), Electron Beam Melting (EBM), Ultrasonic Consolidation (UC), Fused Deposition Modeling (FDM), and Stereolithography (SLA). The RPC has become an industry leader in Additive Manufacturing applications with expertise and funded research in all areas of Additive Manufacturing. This includes the fundamental understanding of the effect of process variables and properties, material development, design for AM, and testing. AM research areas include the following: 1) Laser Sintering of Polymers - Process control and optimization; Mechanical properties; Hardware improvements; Materials research and development; and, High temperature materials; 2) Additive Metals Processing - Evaluation of process variable on mechanical properties; High performance alloys; and, Post processing parameters e.g. – annealing or heat treating; 3) Advanced Additive Manufacturing Techniques - Multi-material and gradient structures; Embedded electronics; Controllable microstructures; and, Parts

consolidation, internal features, as built mechanisms; and, 4) Testing - Mechanical and Fatigue Testing; Physical properties; and, Particle size characterization. The RPC and its associated personnel and faculty are recognized as international leaders in Additive Manufacturing. They are heavily involved in growing and promoting the technology through technical organizations as officers, presenters, and featured speakers.

THE RESEARCH RESOURCES CENTER (RRC): The *in vivo* animal studies will be conducted in the RRC at the University of Louisville Health Sciences Campus. This facility contains approximately 19,450 sq. ft. of animal holding and related support space on a common level. The interior of the building is divided into separate zones called pods. Pods are used according to 1) the nature of activities they are to accommodate and 2) the requirements for functional and physical segregation of animals. Space dedicated to small animal housing includes a modified barrier with restricted access for transgenics and a biocontainment zone. Additional space is provided for large animal housing. Space provided for technical support includes modern surgical suites and laboratories for animal diagnostic and necropsy activities. The RRC has two aseptic surgical suites which include an operator scrub area, an animal preparation area, an ICU, and an operating room. The U of L animal care and use program is supported by a well-trained technical staff (senior veterinary technician, laboratory animal technologist, laboratory animal technician, assistant laboratory animal technician, and animal caretaker) that are AALAS, LATg, LAT, ALAT, and AVMA, respectively, certified. In addition, the facility has three full-time Veterinarians on staff. Finally, the RRC program is fully accredited by the American Association for the Accreditation of Laboratory Animal Care (AAALAC).

CENTER FOR REGULATORY AND ENVIRONMENTAL ANALYTICAL METABOLOMICS (CREAM) ANALYTICAL LABORATORY FOR METABOLOMICS - FACILITY is a 1400 sq. ft laboratory in chemistry building room 316 is equipped for bioanalytical chemistry work. Dr. Zhang also has a 150 sq. ft office in the new Shumaker Research Building (SRB) room 349 outfitted with one 3.00 GHz Intel Core2 Duo workstation, one 1.6 GHz Intel Core2 Duo laptop computer, and one Samsung 3-in-1 laser printer. Full secretarial support is available to support Dr. Zhang's teaching and research activities. The support services include machine and electronic shops, library facilities, art and graphics shop, etc. Dr. Zhang has two other 150 sq. ft offices for bioinformatics development in the SRB building (room 343 and 344) fully equipped with online computers and printer systems.

THE CORE PROTEOMICS LABORATORIES – FACILITY are directed by Jon B. Klein, MD, PhD and Michael L. Merchant, PhD. Dr. Klein is a Professor of Medicine and Biochemistry and holds the James Graham Brown Endowed Chair in Proteomics. Dr. Merchant is an Associate Professor in the Department of Medicine, University of Louisville and is the Technical Director of the Proteomics Laboratories. These facilities operate with the contributions of four technicians and one post-doctoral fellow. The Proteomics Laboratories have 1,475 sq. ft of dedicated space in the Donald Baxter Research Building for core projects. The MS instruments, all HPLC enabled, include a UHPLC-nanospray-Thermo Orbitrap Elite equipped with ETD fragmentation, a Thermo LTQ ion trap, TSQ triple quadrupole instrument, an ABI Q-Star qTOF instrument and ABI 4700 MALDI TOF-TOF. Additionally, one AB Biovision FPLC and one Dionex U3000 microflow instrument are utilized for preparative and semi-preparative protein and small molecular purification. Dr. Merchant and Dr. Klein each have 679 sq. ft of research space in the Donald Baxter Research Building. Dr. Merchant's space is used to conduct research funded by the NIDDK-NIH to confirm biomarkers of hypo-responsiveness to erythropoiesis stimulating agents as well as collaborative research projects. Dr. Klein's space is dedicated to research funded by the NIDDK – U01 Consortium for Biomarkers of Chronic Kidney Disease Research, NIDDK UM1 CureGN Consortium. All these laboratories are located in the state-of-the-art Donald E. Baxter Biomedical Research Building (opened in 1999).

BIOPHYSICS CORE LABORATORY – FACILITY consists of 1000 sq ft of laboratory space which is located on the 2nd floor of the CTR Building. This laboratory was specifically designed to house the core facility, and features ten separate electrical circuits such that most instruments are provided with a dedicated power line. The laboratory has its own water purification system. Dr Chaires's 120 sq ft office is located in the CTR building. A personal computer is available in this office along with a photocopier, fax machine and digital scanner. Additional administrative support is provided by the Brown Cancer Center, as required. The intellectual environment in the Brown Cancer Center is outstanding. The Cancer Biophysics Group is housed together on the 2nd floor of the CTR building to facilitate interactions. The group includes, in addition to Drs. Chaires and Trent; Dr. Hong Ye, and expert in X-ray crystallography. The Biophysics group holds regular meetings and group discussions to further their mutual interests. The Brown Cancer Center also has an active Molecular Targets group that holds weekly seminars. The Brown Cancer Center is an active, vibrant collection of clinical, translational, and basic scientist. Under the leadership of Dr. Donald Miller, the Center has recruited and hired over 80 new faculty members in the last 7 years.

MOLECULAR MODELING CORE - FACILITY: Dr. Trent is the Director of the Modeling Core at the JG Brown Cancer Center. The Modeling Facility moved to 800sq ft. custom renovated space in the CTR Building in 2009. We created a Mac OSX grid cluster of over 25,000 processors which aids in virtual screening using Autodock, Surflex, and DOCK and provides over 800 CPU years a month. The computational lab comprises of six G5/intel Macs, three PC's and a 440 2.6MHz processor core IBM 1350 server with 24 TB attached storage on the second floor of the Clinical and Translational Research Building. A 2x2070 Tesla GPU computing machine is located in the Core as well as a 135TB storage unit.

MEDICINAL CHEMISTRY FACILITY: Dr. Burlison is the Director of the newly established Medicinal Chemistry Facility at the JG Brown Cancer Center. It is housed on the second floor of the CTRB, with 2000 sq ft of dedicated space. Medicinal chemistry is an integral part of an interdisciplinary approach towards the discovery, development and evaluation of new small molecules for the treatment of various indications. By delivering new chemical entities with drug-like properties through synthetic modification, medicinal chemistry may be utilized to develop structure-activity relationships, solve pharmacological problems, drug optimization, and to mitigate metabolic and toxicity liabilities. As a new initiative at the Brown Cancer Center lead by Dr Trent, in August 2011 a new Medicinal Chemistry Facility that is capable of offering medicinal chemistry support and consultation for the Brown Cancer Center community has been set up. A Medicinal Chemist has been recruited to lead the new Facility which is housed in custom renovated 2000 sq. ft. space on the second floor of the CTR Building. Medicinal Chemistry Services we offer include: Optimization of lead compounds, provide synthetic and medicinal chemistry support, development of structure-activity relationships, improvement of ADMET properties in lead compounds, preparation of probes and fluorescently labeled derivatives, synthesis of known ligands for a molecular target, consultation on early stage drug discovery programs. . The facility is capable of rapidly synthesizing and characterizing small molecules to provide structure-activity relationships and lead optimization by improving physicochemical and drug-like properties. Equipment readily available to the Medicinal Chemistry Facility includes one or more of the following dedicated equipment: Agilent 400 MHz NMR equipped with an autosampler, Agilent HPLC/MS equipped with autosampler and a time-of-flight detector, Biotage Initiator Eight Microwave Synthesizer, Teledyne Isco Combiflash purification system, VWR sonicator water bath, VWR microcentrifuge galaxy, Mettler-Toledo balances, Buchi rotary evaporators, seven chemical fume hoods, and standard organic chemistry glassware and equipment. The facility has online access to SciFinder and an array of journals through the University Libraries system.

NUCLEAR MAGNETIC RESONANCE (NMR) CORE FACILITY is a purpose-built suite in the imaging wing of the James Graham Brown Cancer Center (JGBCC) that occupies 2,365 sq. feet. This comprises a console room (966 sq. ft.), a separate magnet room with its own climate control and ultra-low vibration concrete floor (1,020 sq. ft.), a utility room where compressors and water chillers are housed (202 sq. ft.), and the manager's office (177 sq. ft.). The facility can be entered only via a keyed security door, which is accessed by authorized personnel only. The console room also houses bench space for sample manipulation, including a chemical hood, deionized water supply, balance, microfuge, pH meter, chemical storage cupboard, and both 4° and -25°C refrigerators for sample storage. Workstations are lined along one bench, where a small library of reference NMR-based books and journals are kept. The manager's office leads off the main console room, and is equipped with personal computers, a workbench and has Internet access. The facility has a chemical hood, de-ionized water, balance, pH meter and microfuge, plus -25°C/4°C storage. General information is available on the Cancer Center Web site (http://www.browncancercenter.org/ research/shared-research-facilities/nmr-suite/), that describes sample requirements and general capabilities as well as fee structures.

Oral Immunology and Infectious Diseases Core Facility is housed in the School of Dentistry Room 214 (~1100 sq. ft) and includes pH meters (2), CO_2 incubators (4), cell culture hoods (2), nanodrop spectrophotometer, BioRad and Thermo uV/vis spectrophotometers (3), Applied BioScience 7500 real time PCR, BioRad MyCycler PCR (3), microbiologic incubators (3), two station anaerobic culture chamber, baking ovens (2), LabConco lyophilizer, Sorvall high speed centrifuges (2), Sorvall WX ultracentrifuge, Sorvall Legend tabletop centrifuge, liquid nitrogen tanks (3), water baths (3), Mettler analytical balance, Ohaus Scout Scale, Agilent 2100 BioAnalyzer, Eppendorf microcentrifuges (2), Zeiss microscopes (2), Olympus FluoView 500 laser scanning confocal microscope linked to Volocity Image analysis software, BD FACSCalibur cell sorter, Alpha Innotec FluorChem imaging system, Amersham FPLC system, a Blitz surface plasmon resonance instrument, and sonicators (2).

Molecular, Cell and Craniofacial Biology and the Birth Defects Center Core Facility consists of Microscopy/Imaging: Arcturus Pixcell IIe Laser Capture Microdissection System with epifluorescence optics; Nikon Eclipse TE2000U inverted phase contrast microscope with epifluorescence optics and color digital & high resolution monochrome cameras and link to Metamorph Image Analysis System; four Nikon stereoscopic zoom SMZ 1500 microscopes with epifluorescence optics, color digital & high resolution monochrome cameras and links to Metamorph Image Analysis System; Nikon Optiphot microscope with epifluorescence optics, color digital & high resolution monochrome cameras and link to Metamorph Image Analysis System; Nikon SMZ800 Stereoscope with micromanipulators/ injectors; Narashige PN3- Needle Puller; LKB Nova Ultra microtome; two Leica CM 1900 Cryostats; two Leica 2150 RM Microtomes; Shandon Histocenter Embedding Station. Additional analytic equipment include: Qiagen Pyromark Q24 Pyrosequencer; Applied BioSystems ViiA 7 real-time PCR system with 'FAST' kinetic 384-well, and Array Card block; two Perkin Elmer 9700 Thermal Cyclers; two Applied Biosystem PRISM Sequence Detection Systems (TaqMan Real-Time Quantitative PCR); Agilent 2100 "Lab on a Chip" Bioanalyzer; NexCellom CellCounter; Affymetrix GeneChip System (Fluidics Station, Hybridization Station, Scanner) for mRNA, miRNA, CHIP arrays, and SNP chip; Pharmacia Gene Quant Pro spectrophotometer; Victor X3 Multilabel Plate Reader; NanoDrop ND-1000 UV-Vis Spectrophotometer; Turner Luminometer; GE ImageQuant 4000 Image Analysis System; UVP BioDoc-IT Imaging System; Molecular Dynamics StormPhosphoimager; Delta300 Liquid Scintillation System.

8. Governance and Administration of the PhD in Interdisciplinary Studies with Specialization in Translational Bioengineering (ISSTBE) Program

The proposed ISSTBE PhD Program will be a doctoral track within the School of Interdisciplinary and Graduate Studies. Its faculty will be comprised of faculty from the Speed School of Engineering, School of Medicine, College of Business, and School of Dentistry. The following departments and programs within the participating units include:

Speed School of Engineering: Departments of Bioengineering, Chemical Engineering, Computer Engineering and Computer Science, Electrical and Computer Engineering, Industrial Engineering and Mechanical Engineering.

School of Medicine: Anatomical Sciences and Neurobiology, Biochemistry & Molecular Biology, Microbiology & Immunology, Pharmacology & Toxicology, Physiology & Biophysics, Neurological Surgery

College of Business: Entrepreneurship MBA

School of Dentistry: Oral Biology, Oral Immunology and Infectious Diseases, Molecular, Cell and Craniofacial Biology

The Bioengineering Graduate Program Director will serve as a Co-Director of ISSTBE PhD Program, and the other ISSTBE Program Co-Director will be appointed by the Bioengineering Department Chair. The ISSTBE PhD Program will be governed by an Executive Committee, which will be comprised of the Program Co-Directors and faculty from each of the collaborating units. The Executive Committee will report to the Dean of the School of Interdisciplinary and Graduate Studies. The Executive Committee will be established as follows:

- Membership:
    - In addition to the Co-Directors of the ISSTBE Program, the Executive Committee will consist of one faculty representative from each participating school/college. Executive Committee members must have graduate faculty status and expertise relevant to ISSTBE Program goals. Schools with multiple participating departments will have at least two representatives, each from unique participating departments. Initially, the Program Co-Directors will select members of the Executive Committee. Subsequently, the Executive Committee will nominate, approve and confirm members.
    - ISSTBE Program Co-Directors will be permanent members of the Executive Committee. Other members will serve either a 2 or 3-year term to allow for a staggered rotation; one half of the Committee will serve a 2-year term and the other half will serve a 3-year term. Members may serve multiple consecutive terms if confirmed by the Executive Committee.
- Executive Committee Chair and Vice Chair:
    - The Program Co-Directors will serve as Chair and Vice Chair of the Executive Committee.
- Committee Responsibilities:
    - The Executive Committee will have oversight for all aspects of the ISSTBE Program, including application review and admissions, curriculum content assessment and development, student recruitment and advertising, approval of dissertation committees and reporting to SIGS. The Executive Committee will also be responsible for reviewing annual progress reports for each student, including an assessment from the student's mentor.
    - Ad hoc committees may be established as deemed necessary, with responsibilities and membership determined by the Executive Committee.

- The Executive Committee may adopt rules and procedures as needed, provided they are consistent with those of the University and SIGS. Modifications or additions to rules and procedures will require approval by two-thirds of Executive Committee's members.
- The Executive Committee may at their discretion conduct portions of their business electronically provided members' privileges are not adversely affected.

9. Admission, Retention, and Completion Standards

The School of Interdisciplinary and Graduate Studies has rigorous standards for admission into doctoral programs, and those standards will apply to the ISSTBE PhD program as well. Applicants must meet SIGS admission requirements along with additional Program requirements. Applicants must, as a minimum, have completed a Bachelor's Degree in Engineering from an accredited program or Medical Physics with a 3.25 cumulative GPA to be considered for admission. Applicants with an undergraduate GPA of 3.0 will be considered for provisional acceptance; however, they must maintain a 3.25 GPA at a minimum in their first year of study or they will not be allowed to continue in the program. The ideal applicant will have completed either a Master's (MS or MEng) Degree in engineering at the time of application. Applicants must submit: 1) transcripts of all college-level courses; 2) three letters of recommendation; 3) a written statement by the applicant describing previous experience related to bioengineering; 4) a statement as to how the PhD ISSTBE will allow them to fulfill their career goals as identified by their focus area of interest; and, 5) GRE verbal, quantitative and writing assessment-analytical scores. GRE scores at or above the 60th percentile on verbal and quantitative sections will be required for admission. Students whose native language is non-English or degree is from a non-US accredited institution are required to submit TOEFL scores (administered by the Educational Testing Service). A minimum TOEFL score of 79 or higher on the internet-based test or 550 or higher on the paper-based test is required. Alternatively a minimum of 6.5 on the International English Language Testing System will be accepted.

The School of Interdisciplinary and Graduate Studies has developed the PLAN (http://louisville.edu/graduate/plan), which is an effort aimed at improving graduate student development and retention, providing seminars and workshops on **Professional** development, **Life** skills, **Academic** development, and **Networking** skills. Students in the PhD ISSTBE program will be encouraged to attend these seminars and workshops.

Student performance will be monitored and assessed throughout their program using the following metrics to assure that students completing the program are highly competent experts in the field of Bioengineering.

- Course performance (GPA)
- Qualifying Examination outcomes
- Comprehensive Examination outcomes
- Quality of presentations at Bioengineering Seminar Series
- Submission of peer-reviewed journal papers and conference papers by students as first authors
- Presentations at regional, national and international conferences by students
- Intellectual property submitted, filed and/or issued with students as co-inventors
- Dissertation defense performance

10. Degree Completion Requirements

Students must pass the Qualifying Examination, complete 47 credit hours of course work beyond their Bachelor's Degree (18 Core credits, 9 Concentration credits, 20 Specialization credits), participate in the Bioengineering Seminar Series (75% attendance rate and 1 presentation/term as a Doctoral Candidate), pass

the Comprehensive Examination, successfully defend their dissertation (15 credit hours) and submit two or more peer-reviewed journal papers representing their original dissertation research to meet the requirements of the PhD ISSTBE.

The PhD Qualifying Examination will be offered once per year and is to be taken by students upon completion of Core courses (with the exception of Bioengineering Seminar credits) and Concentration Area courses. The Qualifying Examination includes written and oral components. The written portion of the exam gauges student competency in fundamental bioengineering topics covered in their courses. ISSTBE affiliated faculty will submit and grade questions in their respective areas of expertise for the written portion of the Qualifying Examination. The oral portion of the examination is a formal presentation comprised of the student's critique of a peer-reviewed journal paper selected from the student's area of concentration, delivered to the ISSTBE Program Director and a subset of faculty with expertise in the respective concentration having Graduate Faculty status. Students are allowed no more than two opportunities to take the Qualifying Examination (oral or written components).

By the end of the 1st semester, it is expected that the student has identified their Dissertation Chair. After the 1st year of study, the student (under the guidance of his or her advisor) must select a Dissertation Committee of five or more persons, for approval by the Program Director. The committee must consist of the student's advisor from the Department of Bioengineering (who will act as the Dissertation Committee Chair), at least two additional faculty members from within the Department of Bioengineering, at least one faculty member from a partnering School or College, and at least one additional faculty member from outside the Department of Bioengineering.

Formal admission to PhD candidacy signifies approval for the student to devote exclusive attention to their original dissertation research and writing of their dissertation. To qualify for candidacy, students must pass the Qualifying Examination, maintain a minimum GPA of 3.0 and pass the Comprehensive Examination. The Comprehensive Examination requires the student to prepare a written dissertation research proposal (following an external funding agency format) that is presented, defended and approved by their Dissertation Committee. Dissertation Committee approval constitutes passing both the written and oral portions of the Comprehensive Examination. The written portion is comprised of the student's dissertation document and the oral portion consists of the student's presentation and defense of their dissertation, including response to questions posed by their Dissertation Committee and public attendees. The Dissertation Committee will grade written and oral performance on the Comprehensive Examination separately as a 'pass', 'conditional pass', or 'fail'. Students receiving a 'conditional pass' must satisfactorily meet conditions set forth by the Dissertation Committee in order to receive a passing grade. Students receiving a failing grade on either or both portions of the Comprehensive Examination will be permitted to repeat the respective portion(s) once. Students must meet with their Dissertation Committee at least once per year during the remainder of their PhD program, culminating in the Dissertation Defense.

11. Provide the following information for the program and for each concentration (some categories may not apply to all programs):

a. Total number of hours required for degree: 62 cr beyond the Bachelor's degree
b. Number of hours in degree program core: 18 cr
c. Number of hours in concentration: 9 cr
d. Number of hours in guided electives: 20 cr
e. Number of hours in free electives: n/a

f. Number of hours in dissertation research: 15 cr

12. Describe how the proposed program will articulate with related programs in the state. It should describe the extent to which student transfer has been explored and coordinated with other institutions. Attach all draft articulation agreements related to this proposed program.

Transfer of credits from a Master's Degree or PhD program in engineering or medical physics from an accredited institution is permitted. However, the number of transfer credits (up to a maximum of 12 credit hours) will be evaluated on a case-by-case basis by the PhD ISSTBE Program Executive Committee, which will forward the petition to the Dean of the School of Interdisciplinary and Graduate Studies for final approval. Sufficient course descriptions and a transcript must accompany the petition so that the request can be evaluated.

13. List courses under the appropriate curricular headings

The student, working together with their advisor prior to completing Core Courses, must develop a Plan of Study. The Plan of Study must identify elective courses in the student's selected Concentration Area, as well as guided electives needed to fulfill the student's Specialization. The Plan of Study must be reviewed and approved each term by the student's advisor. The Plan of Study may be modified with approval from the student's advisor. A list of course descriptions is shown in Appendix C.

Core Courses			
Prefix & Number	Course Title	Credit Hours	New
BE 695	Advanced Research Design & Methods	3	Y
BE 621	Bioinstrumentation	4	N
BE 654	Advanced Physiology for Engineers	3	N
BE 601	Bioengineering Seminar	1 ea. (3)	Y
BE 603	Research Ethics in Bioengineering	2	Y
ME 565	Advanced Engineering Mathematics I	3	N
	TOTAL CORE CREDIT HOURS	18	
Elective Courses in Concentration Areas – 9 credits in one of the following concentration areas			
Molecular and Tissue Engineering ✓			
Prefix & Number	Course Title	Credit Hours	New
BE 552	Tissue Engineering	3	N
BE 683	Artificial Organs	3	N
BE 605	Tissue & Molecular Biology Techniques	3	N
BE 650	Advanced Biomaterials	3	N
BIOC 680	Biomolecular Interactions	3	N
BIOC 668	Molecular Biology	3	N
BIOC 611	Biochemical & Molecular Methods	3	N

Bioimaging and Biocomputational Modeling ✓			
Prefix & Number	Course Title	Credit Hours	New
BE 600	Modeling of Biological Phenomena	3	N
BE 640	Computational Methods for Medical Image Analysis	3	N
CECS 622	Simulation and Modeling of Discrete Systems	3	N
CECS 624	Advanced Simulation	3	N
CECS 627	Digital Image Processing	3	N
Bioelectrical and Biomedical Devices ✓			
Prefix & Number	Course Title	Credit Hours	New
BE 680	BioMEMS	3	N
BE 653	Nanoscale Bioengineering	3	N
ECE 543	Microfabrication and MEMS	3	N
ME 640	Optimum Design Methods	3	N
ME 647	Advanced Design Methods	3	N
Biomechanics and Rehabilitation ✓			
Prefix & Number	Course Title	Credit Hours	New
BE 658	Injury Biomechanics	3	N
BE 639	Rehabilitation Engineering	3	N
BE 611	Cardiovascular Dynamics I	3	N
BE 612	Cardiovascular Dynamics II	3	N
ME 651	Kinematics & Kinetics of Human Movement	3	N
ME 652	Advanced Human Dynamics	3	N
ME 650	Biofluid Mechanics	3	N
ME 638	Continuum Mechanics	3	N

Courses in Specialization – Guided Electives – 20 credits

Courses in Specialization must be unique from those taken to fulfill the Concentration Requirement, and must follow either Track A, B or C below. Students must work with their advisor to establish a Plan of Study for Specialization Courses. All Specialization courses must be approved by the student's advisor prior to registration.

Track A. Traditional Bioengineering Research PhD – 18 credits from those listed below with a minimum of 6 credits in engineering courses + Teaching Practicum (2 credits)

Track B. Clinical-Translation Research PhD – 12 credits from list below designated as BIOC, ASNB, PSYC, BIOL, MBIO, OBIO or EXP; remaining 6 credits

from BE, CECS, ECE, IE, or ME + Clinical Practicum (2 credits).
Track C. Advancing Bioengineering Technologies through Entrepreneurship PhD – Nucleus Lean LaunchIT Start Up Course (3 credits), plus 12 credits from list below designated as ENTR or IMBA; remaining 6 credits from BE, CECS, ECE, IE, ME + Teaching Practicum (2 credits).

Prefix & Number	Course Title	Credit Hours	New
BE 600	Modeling of Biological Phenomena	3	N
BE 683	Artificial Organs	3	N
BE 605	Tissue & Molecular Biology Techniques	3	N
BE 650	Advanced Biomaterials	3	N
BIOC 680	Biomolecular Interactions	3	N
BIOC 668	Molecular Biology	3	N
BIOC 611	Biochemical & Molecular Methods	3	N
BE 640	Computational Methods for Medical Image Analysis	3	N
CECS 622	Simulation and Modeling of Discrete Systems	3	N
CECS 624	Advanced Simulation	3	N
CECS 627	Digital Image Processing	3	N
BE 680	BioMEMS	3	N
BE 653	Nanoscale Bioengineering	3	N
ME 640	Optimum Design Methods	3	N
ME 647	Advanced Design Methods	3	N
BE 639	Rehabilitation Engineering	3	N
BE 658	Injury Biomechanics	3	N
BE 611	Cardiovascular Dynamics I	3	N
ME 651	Kinematics & Kinetics of Human Movement	3	N
ME 652	Advanced Human Dynamics	3	N
ME 650	Biofluid Mechanics	3	N
ME 638	Continuum Mechanics	3	N
BE 653	Nanoscale Bioengineering	3	N
BE 693	Independent Study	3	N
ME 566	Graduate Engineering Mathematics	3	N
ME 671	Advanced Fluid Dynamics	3	N
BIOC 645	Advanced Biochemistry	4	N
ASNB 602	Fundamentals of Neuroscience	3	N
ASNB 614	Molecular Neurobiology	4	N
ASNB 617	Developmental Neurobiology	4	N
CECS/ECE 643	Introduction to Biomedical Computing	3	N
CECS 628	Computer Graphics	3	N
CECS 633	Computer Vision	3	N

CECS 660	Introduction to Bioinformatics	3	N
ECE 520	Digital Signal Processing	3	N
ECE 521	Digital Signal Processing Laboratory	1	N
ECE 523	Introduction to Biometrics	3	N
ECE 543	Microfabrication and MEMS	3	N
ECE 544	Microfabrication/MEMS Laboratory	1	N
ECE 562	Introduction to Robotics	3	N
ECE 564	Fundamentals of Autonomous Robots	3	N
ECE 565	Autonomous Robots Laboratory	1	N
ECE 614	Artificial Neural Systems	3	N
ECE 661	Sampled-Data Control Systems	3	N
ECE 662	Introduction to Optimum Control	3	N
ECE 676	Foundations of Polymer MEMS	3	N
MBIO 601	Molecular Microbiology	2	N
MBIO 602	Immunology	3	N
MBIO 610	Methods & Analysis in Biomedical Sciences	2	N
MBIO 618	Cell Biology of Viruses	3	N
MBIO 658	Cellular & Molecular Immunology	3	N
MBIO 670	Molecular Virology	3	N
PHTX 655	Neuropharmacology	2	N
PHTX 656	Cardiovascular & Renal Pharmacology	2	N
PHTX 657	Endocrine and Metabolic Pharmacology	2	N
PHTX 660	Principles of Drug & Chemical Action	2	N
OBIO 501	Biomedical Data Analysis	3	N
OBIO 601	Intro to Oral Biology Research	2	N
OBIO 600	Concepts in Oral Immunology	2	N
OBIO 604	Oral Microbiology	3	N
OBIO 611	Craniofacial Osteology	3	N
OBIO 612	Craniomaxillofacial Diagnostic Imaging	3	N
OBIO 617	Advanced Oral Pathology	1	N
ME 566	Advanced Engineering Mathematics II	3	N
IE 563	Experimental Design in Engineering	3	N
IE 681	Human Performance	3	N
ENTR 600	Business Plan Development	3	N
IMBA 652	Business Plan Competition I	3	N
IMBA 654	Business Plan Competition II	3	N
IMBA 664	Business Plan Competition III	3	N
BE 696	Evidence Based Entrepreneurship	3	N

BE 688	Teaching Practicum	2	Y[1]
BE 692	Clinical Rotation	2	Y[2]

[1] – Required for Traditional Bioengineering Research Track and Advancing Bioengineering Technologies through Entrepreneurship Track

[2] – Medical school or dental school clinical rotation in the student's area of interest (e.g. neurology, pediatrics, etc.) required for Clinical Translation Research Track. Selection and registering for courses must be coordinated with advisor and Director of Program.

14. Alternative Methods of Program Delivery

All courses will be delivered in a face-to-face classroom setting style lecture or clinical setting. No distance learning or alternative means of course delivery is available at this time.

15. If the proposed program is an advanced practice doctorate, describe how the doctorate builds upon the reputation and resources of the existing master's degree program in the field.

The proposed doctoral program is not an advanced practice doctorate.

16. Impact Upon Undergraduate Program

The proposed doctoral program will enable graduates of the Bioengineering BS program to advance their education and research to a higher level, in which they will work towards completing a MEng thesis and graduate level courses that will prepare them for our rigorous doctoral program. The BS degree in bioengineering is ABET accredited through June 30, 2018. The BS and PhD programs will be complementary and provide synergistic education and research opportunities for undergraduate (BS) and PhD students through expanded R&D teams comprised of undergraduate and graduate engineering, medical, dental, and business students. Doctoral students will also have the opportunity to gain teaching experience under mentorship of BE faculty serving as instructors for undergraduate courses in the bioengineering undergraduate curriculum, which enhance the learning environment for students in the undergraduate program. Collectively, these extraordinary education and research opportunities will build upon the solid foundation and strong national reputation of our ABET accredited bioengineering undergraduate (BS) degree program.

17. If the proposed program is an advanced practice doctorate, list and discuss the nature and appropriateness of available clinical sites. Supply letters of commitment from each clinical site that specifies the number of students to be accommodated and identifies other academic programs that also use the facilities.

Not applicable as the proposed program is not an advanced practice doctorate.

C. Program Demand/Unnecessary Duplication

1. Student Demand

a. Evidence at regional, state, and national levels

In a report[5] by Dr. Brian Yoder and the *American Society of Engineering Education* in 2012, student enrollment in biomedical engineering Ph.D. programs has increased nearly 4-fold since 2003 while, on

[5] http://www.asee.org/papers-and-publications/publications/11-47.pdf

average, all other engineering programs have seen less than a 2-fold increase over the same 10-year period. This report also states that bioengineering undergraduate enrollment has increased nearly 110% while the traditional engineering disciplines have only seen a slight increase (~30%). These significant increases in number of graduates from undergraduate and graduate bioengineering/biomedical engineering clearly demonstrate the student demand for doctoral level PhD programs.

b. Describe the applicant pool and how they will be reached

Prospective students will be those who have completed a Bachelor's or Master's (MS or MEng) degree in engineering from an ABET accredited school or those who have completed a Bachelor's or Master's degree in Medical Physics. Students will be recruited through web-based marketing of the programs, along with advertisement of the program at regional, national and international bioengineering society conferences. Program announcements will be sent to top-ranked engineering schools and bioengineering focused companies.

c. Identify the primary feeders for the program.

Speed School of Engineering undergraduate and graduate programs will serve as a primary feeder for the proposed program. Additionally, graduates from the University of Kentucky College of Engineering will also be likely applicants to the PhD ISSTBE given its unique interdisciplinary nature. Accredited engineering schools across the US will also serve as feeders for the program. Given the national recognition of our BE faculty, it is reasonable to expect that engineering graduates from across the nation will find our program attractive.

d. Evidence of net increase in student enrollment

As reported in the "Student Demand" section above, the number of PhD students graduating from bioengineering/biomedical engineering programs has increased 4-fold over the past 10 years. The number of students enrolled in PhD bioengineer/biomedical engineering programs across the country in 2012 was 6,103 compared to 2,903 in 2003. This represents a 110% increase in PhD student enrollment in bioengineering/biomedical engineering programs compared to a 30% increase in all other engineering disciplines. In addition, the Bachelor of Science and Master of Engineering in Bioengineering degree programs have grown significantly over the past nine years. In 2005, a total of 15 students entered the first freshman class of bioengineering and, in 2014, the incoming class consists of 93 freshman that have designated bioengineering as their chosen discipline. In 2009, our first graduating class of MEng degree in Bioengineering consisted of four graduates, while in the 2014 academic year, 25 students completed our MEng degree program. Thus, we anticipate a net increase in student enrollment associated with the PhD ISSTBE.

e. Project estimated student demand for the first five years of the program.

Based on similar programs across the country and faculty resources during the first five years of the program, we project 10-12 applicants per year with a projected enrollment of 3-5 new students admitted and enrolled annually. The first graduates of the program are expected by the fifth year of the program. Based upon graduating BS and MEng bioengineering students at the University of Louisville, it is anticipated that approximately one-half of doctoral students will enroll in the Traditional Bioengineering Research track, one-quarter in Clinical Translational Research track, and one-quarter in Advancing Bioengineering Technologies through Entrepreneurship track.

Table 1. A conservative estimate of the number of students in the program on an annual basis.

Academic Year	Doctoral Candidacies	Degrees Conferred	Majors (Headcount) – Spring Semester
2015-16	0	0	2
2016-17	0	0	4
2017-18	3	0	6
2018-19	5	1	8
2019-20	9	3	10

2. *Employer Demand*

US News and World Report published in 2012 that Bioengineering is one of the fastest growing disciplines in industry and academic research positions, with continued growth expected over the next decade. Specifically, Biomedical Engineering was listed as one of the '11 Hot College Majors', in which "the folks standing at the intersection of the life sciences, engineering and medicine can enjoy exciting work – and a stable job outlook." The Bureau of Labor Statistics estimates the bioengineering field will see 62 percent growth in jobs between 2010 and 2020. Graduates of the PhD ISSTBE program will be highly competitive for post-doctoral and faculty positions at academic institutions (average salary $80,000), industry (average salary $100,000; medical device industry, start-up companies), or professional medical and dental school applicants at academic institutions.

3. Academic Disciplinary Needs: Clearly describe all evidence justifying a new program based on changes in the academic discipline or other academic reasons.

Development of the ISSTBE Program is based upon demand in this relatively new discipline. There are no known or anticipated changes in this academic discipline at this time.

4. Similar programs: A new program may serve the same potential student population, the proposed program must be sufficiently different from existing programs in the state or access to existing programs must be sufficiently limited to warrant initiation of a new program.

The proposed PhD ISSTBE is unique to Kentucky, and very few programs offering clinical translational and entrepreneurship focused bioengineering doctoral degrees exist in the US. The only universities in the Commonwealth of Kentucky to offer degrees in bioengineering and/or biomedical engineering are the University of Louisville and the University of Kentucky. The proposed doctoral program focuses on areas that are not highly emphasized at the University of Kentucky. Specifically, three tracks will be offered in the proposed program in the areas of traditional bioengineering research, clinical translational research and advancing bioengineering technologies through entrepreneurship. Additionally, the proposed doctoral program consists of four identified concentration areas: 1) Bioelectronics and Biomedical Devices; 2) Bioimaging and Biocomputational Modeling; 3) Biomechanics and Rehabilitation; and, 4) Molecular and Tissue Engineering. On the other hand, the University of Kentucky only offers a traditional biomedical engineering Ph.D. program which focuses on the following research areas: 1) Biomaterials and Tissue Engineering; 2) Biophotonics; 3) Cardiovascular and Neural Control; and, 4) Cellular and Musculoskeletal Biomechanics.

a. Southern Regional Education Board (SREB) and National

There are currently 114 PhD programs in the United States in the area of bioengineering, biomedical engineering, or related fields (http://graduate-school.phds.org), with the yearly total number of student

applications in the thousands with an annual admittance number that may exceed 2000. The large number of applicants illustrates the competitiveness for students seeking a formal training in bioengineering at the PhD level. The majority of the University of Louisville's seventeen CPE-approved benchmark institutions (except for SUNY at Buffalo, Temple, and University of New Mexico) have PhD programs in bioengineering, biomedical engineering, or related fields. Additionally, compared to all schools in the Atlantic Coast Conference, the University of Louisville is the only institution without a PhD program in bioengineering and/or biomedical engineering. Thus, the University of Louisville is lagging behind its benchmark institutions in terms of providing formal graduate doctoral training in bioengineering.

http://louisville.edu/institutionalresearch/benchmark-institutions/benchmark-institutions.com

Institutions within a 250 mile radius of the University of Louisville offering a Bioengineering (or related) doctoral degree include Washington University in St. Louis (Biomedical Engineering), Purdue University in West Laffayette (Biomedical Engineering and Biological and Agricultural Engineering), Vanderbilt University in Nashville (Biomedical Engineering) and University of Kentucky in Lexington (Biomedical Engineering). While complete enrollment and matriculation information is not available for these programs, based on the limited information available, the average number of students accepted into these programs ranges from 10-20 doctoral students annually.

In 2013, the Department of Bioengineering faculty had federal, state and private foundation grants and industry contracts representing over $3.5 million in research expenditures. Through the PhD ISSTBE, our faculty and students will be able partner with clinicians, scientists, and students on the medical campus as well as entrepreneurs in the business school and community to conduct translational research and advance bioengineering technologies. These collaborations will provide extraordinary opportunities for graduate student training as well as new research funding opportunities. Our proposed educational paradigm (clinical translational research and entrepreneurship) will also enable continued growth and expansion of our Wallace H. Coulter Foundation Translational Partnership Award.

b. If similar programs exist in Kentucky,

i. Does the proposed program differ from existing programs? If yes, please explain.

The University of Kentucky (UK) College of Engineering offers a BS Degree in Biosystems Engineering and other engineering disciplines, along with MS and PhD degrees in Biomedical Engineering. The UK PhD program in Biomedical Engineering centers on the application of engineering to human health where as the proposed U of L PhD ISSTBE emphasizes the application of engineering to advance human health and quality of life through the translation of innovations. The UK PhD program concentrates on traditional biomedical engineering education curriculum and dissertation research with research foci in the areas of: 1) Biomaterials and Tissue Engineering; 2) Biophotonics; 3) Cardiovascular and Neural Control; and, 4) Cellular and Musculoskeletal Biomechanics. On the other hand, the research and curricular foci in the U of L Department of Bioengineering are in the areas of: (1) Bioelectronics and Biomedical Devices; (2) Bioimaging and Biocomputational Modeling; (3) Biomechanics and Rehabilitation Engineering; and, (4) Molecular and Tissue Engineering. In addition, the proposed Ph.D. program will have three Tracks that students can choose: (A) Traditional Bioengineering Research; (B) Clinical Translational Research; and, (C) Advancing Bioengineering Technologies through Entrepreneurship. This program will be accomplished through partnering with Schools and Colleges throughout U of L to deliver a broad, comprehensive, multi-disciplinary educational and research experience. Our proposed PhD ISSTBE is unique to the Commonwealth providing students with opportunities to focus on Clinical Translational Research or Advancing Bioengineering Technologies through Entrepreneurship. We are aware of only two other PhD programs in Bioengineering in the US (Pennsylvania University, University of

Colorado-Denver) offering a Track that brings together the development of bioengineering technologies and entrepreneurship to promote commercialization of technologies to address clinical needs.

ii. Does the proposed program serve a different student population (i.e., students in a different geographic area) from existing programs? If yes, please explain.

Yes, the proposed PhD ISSTBE program at U of L targets a different student population from other doctoral programs both in the State of Kentucky, regionally, and nationally. Students seeking the proposed doctoral program will be able to pursue training as either a clinical or entrepreneurial translational researcher or as a traditional bioengineering researcher gaining expertise in one of the four research and curricular foci areas within bioengineering. Most notably, the Entrepreneurship Track within the PhD ISSTBE will serve a unique student population by providing knowledge and skills important to the creation and leadership of startup companies, aiming to train founders and leaders of tomorrow's high-tech companies.

iii. Is access to existing programs limited? If yes, please explain.

The proposed PhD ISSTBE program is designed for the emerging fields of clinical and translational research and entrepreneurial translation of medical technologies. Very few doctoral programs in the United States offer similar educational curriculum and R&D opportunities as evidenced by U of L selection as one of sixteen prestigious Wallace H. Coulter Foundation Translational Partnership awards. As previously stated, the proposed PhD ISSTBE is unique to the State of Kentucky.

iv. Is there excess demand for existing similar programs? If yes, please explain.

The demand for proposed type of program is growing rapidly; however, there are only a limited number of programs throughout the US offering a similar program or opportunities. Given the current accountability climate in Washington, DC and the US, all federal funding agencies are required to demonstrate how their respective research programs lead to innovations, economic development and employment opportunities for US citizens. The proposed program is designed to provide an impact on health and quality of life by translating bioengineering research and technologies.

v. Will there be collaboration between the proposed program and existing programs?

No, there will not be collaboration with other existing bioengineering programs at this time.

vi. If yes, please explain the collaborative arrangements with existing programs.

D. Cost and Funding of the Proposed Program

1. Will this program require additional resources?

a. If yes, provide a brief summary of additional resources that will be needed to implement this program over the next five years.

Yes. The proposed program will require additional doctoral fellowships. SIGS will provide 4 fellowships to students for a 2-year duration on an on-going basis. Initially, during the first five years of the doctoral program, tuition waiver is requested while students are completing course work. However, the Bioengineering and ISSTBE associated faculty will provide student stipend support while the students are completing their dissertation research.

Course delivery will be provided by Bioengineering faculty along with faculty from Computer Engineering and Computer Science, Mechanical Engineering, Electrical and Computer Engineering, and Industrial Engineering within the Speed School of Engineering. Additionally, faculty from the College of Business (Entrepreneurship), the School of Dentistry (Dentistry and Oral Medicine; Molecular, Cellular and Craniofacial Biology; Oral Health and Rehabilitation; Orthodontics, Pediatric Dentistry and Special Care; and, Surgical and Hospital Dentistry), and the School of Medicine (Anatomical Sciences and Neurobiology, Biochemistry and Molecular Biology, Microbiology & Immunology, Neurological Surgery) will provide course delivery for the PhD ISSTBE.

Note: Other disciplines are expected to be added in the future as our doctoral program matures and grows in breadth, depth, and scope.

2. Will this program impact existing programs and/or organizational units within your institution?
a. If yes, please describe the impact.

SIGS has requested additional fellowship lines from the central administration to support the development of new interdisciplinary graduate programs, but budget constraints have precluded an increase in fellowship lines to SIGS. Thus, the reallocation of fellowship lines may impact the number of University Fellows that can be supported each year who matriculate into existing graduate programs. However, the interdisciplinary interactions are anticipated to complement other organizational units and significantly increase opportunities to pursue NSF and NIH training and research grants, bringing additional revenue and graduate fellowships to the University of Louisville. Participating units will receive degree productivity credit for ISSTBE students based upon student mentor affiliation.

3. Provide adequate documentation to demonstrate sufficient return on investment to the state to offset new cost and justify approval for the proposed program.

Successful implementation of the proposed program will lead to the creation of new innovations and entrepreneurial ventures, which will directly contribute to economic development in the State of Kentucky through the formation of new start-up companies, and may attract established industries to the state. In addition, the program will assist the Commonwealth of Kentucky in achieving its goal of reducing the "brain drain" from the Commonwealth by providing new high-tech employment opportunities for the citizens of Kentucky. The tax revenue created by the creation of new companies, migration of established industries, and retention of a highly paid work force will provide a long-term return on investment. Once the program is fully established, tuition revenue from new students (in most cases supported through research or training grant funding) enrolling in the PhD ISSTBE will be contributed to the University as well as indirect costs associated with the formation of new research collaborations and partnerships.

4. If this is an advanced practice doctorate, provide assurance that funding for the program will not impair funding of any existing program at any other public university.

Not applicable.

D. Cost/Funding Explanation

See attached Excel Sheet entitled Proposal Budget Form – ISSTBE PhD Program

E. Program Review and Assessment

1. *For each assessment method, provide direct indicators of achievement of student learning outcomes*
   a. *Which components will be evaluated and when will they be evaluated?*

   Indicators of Achievement for each Student Learning Outcome will be evaluated annually by the Executive Committee (Table 2).

Table 2. Student learning outcomes to be assessed and associated indicators of achievement.

Student Learning Outcome	Indicators of Achievement
a) demonstrate excellence in their ability to design and conduct original research leading to a unique intellectual contribution to the bioengineering field	Achievement of one or more of the following: 1) accepted first-authored refereed journal and/or conference paper 2) Intellectual property based upon student-developed technology filed, issued and/or licensed to industry 3) fellowship awarded for dissertation research 4) student research-related award 5) successful defense of dissertation
b) demonstrate an in-depth of knowledge of chosen bioengineering concentration area and associated scientific literature	Achievement of one or more of the following: 1) passing grade on Comprehensive Exam 2) admission to Doctoral Candidacy 3) successful defense of Doctoral Dissertation
c) understand the clinical relevance and ethical implications of their research	Achievement of both of the following: 1) completion of BE 603 - Research Ethics in Bioengineering course with an A or B grade 2) passing grade on Comprehensive Exam 3) successful defense of Doctoral Dissertation
d) demonstrate ability to critically analyze, evaluate and interpret research methods and findings	Achievement of one or more of the following: 1) completion of BE 695 – Advanced Research Design and Methods with an A or B grade 2) passing grade on oral component of the Qualifying Examination 3) successful completion of the comprehensive examination 4) successful defense of dissertation 5) accepted first-authored refereed journal and/or conference paper
e) demonstrate ability to effectively communicate knowledge of their concentration area and research orally and in writing	Achievement of one or more of the following: 1) presentation at regional, state, national or international conference 2) accepted first-authored refereed journal and/or conference paper 3) authored book chapter 4) passing grade on Qualifying Examination 5) passing grade on Comprehensive Exam 5) successful defense of dissertation

   b. *When will data be collected?*

Data will be collected at the end of each term.

   c. *How will data be collected?*

Each faculty advisor will complete an online form for each of their students, reporting student Indicators of Achievement related to each Student Learning Outcome for a given term, along with details of each Indicator.

Data from the online forms will populate a Student Learning Outcomes and Indicators of Achievement database.

d. What are the benchmarks and/or targets to be achieved?

Each student receiving a PhD ISSTBE must attain all Student Learning Outcomes as evidenced by meeting associated Indicators of Achievement. However, of students accepted into the Program, we expect 90% will pass their Qualifying Exam, 80% will pass their Comprehensive Exam, and 80% will successfully defend their dissertation and receive a PhD ISSTBE.

e. Individuals and/or groups responsible for data collection?

Each faculty advisor will be responsible for reporting data on their respective students within 1 month following the end of an academic term. Given our proposed use of an online reporting system, data will automatically populate a database maintained by the Program Director.

f. How will data be shared with faculty?

Data from the Student Learning Outcomes and Indicators of Achievement database will be compiled into a written report and shared with the ISSTBE Executive Committee, as well as the Bioengineering Department faculty during an annual retreat. Data will be summarized by Student Learning Outcome, as well as by individual Indicators of Achievement criteria for the student cohort. Additionally, data will be represented for each student (along with their status in the Program) by Student Learning Outcome to assess progress towards meetings Indicators of Achievement.

g. How will data be used for making programmatic decisions?

The Executive Committee will assess overall Indicators of Achievement data relative to benchmark targets. In cases where benchmarks are not being achieved, these deficiencies will be discussed during the annual program retreat. An evaluation of the extent of deficiency will be determined and circumstances associated with the deficiency will be explored in an effort to develop strategies for improvement. Potential strategies will be discussed and voted on by the Executive Committee. Modifications to the Program will be made based upon a majority vote. Effectiveness of modifications will be re-assessed at subsequent annual retreats.

2. Measures of Teaching Effectiveness

The primary measure of teaching effectiveness will be individual course and instructor evaluations completed by students at the end of each course. Students are also able to provide anonymous feedback on course evaluations.

3. Efforts to Improve Teaching Effectiveness

Course evaluations provide direct student feedback to course instructors who are then able to address areas needing improvement. In addition, course evaluations are measured outcomes of teaching performance; as a result, each Department Chair will discuss and address any identified weaknesses with instructors during their annual review. Additionally, course instructors have access to the Delphi Learning Center's monthly workshops designed to improve teaching effectiveness. Typically, these one-hour training workshops are designed to present new teaching approaches, education paradigms, and instruction of emerging technology to improve teaching effectiveness.

4. Evaluation of Students' Post-Graduate Success

Short-term post-graduate success will be defined based upon placement in academic, industry and/or government agency positions. Additionally, establishment of start-up companies by students graduating from the Program will be viewed as post-graduate success. Intermediate and long-term success will be characterized by contributions to the field of bioengineering as evidenced by scientific publications, patents issued, honors, start-up companies established, and professional attainment by alumni. The ISSTBE Program will survey alumni annually for 3 years, and every 5 years thereafter. Additionally, alumni placement will be assessed through the SIGS Alumni Tracking program and the Office of Institutional Research and Planning survey mechanisms.

Appendix A

Translational Bioengineering Mentors

Faculty	Department
Bertocci, Gina	Bioengineering
Bertocci, Karen	Bioengineering
Clouse, Van	Entrepreneurship
Darling, Doug	Oral Immunology & Infectious Disease
Demuth, Donald	Oral Immunology & Infectious Disease
El Baz, Ayman	Bioengineering
Frieboes, Hermann	Bioengineering
Giridharan, Guruprasad	Bioengineering
Keynton, Robert	Bioengineering
Koenig, Steven	Bioengineering/Cardiovasc & Thorac Surgery
O'Toole, Martin	Bioengineering
Roussel, Tommy	Bioengineering
Soucy, Kevin	Bioengineering/Cardiovasc & Thorac Surgery
Soucy, Patricia	Bioengineering
Steinbach, Jill	Bioengineering
Voor, Michael	Bioengineering
Klinge, Carolyn	Biochemistry & Molecular Biology
Wang, Eugena	Biochemistry & Molecular Biology
Keller, Brad	Cardiovascular Innovation Inst. & Pediatrics
Pantalos, George	Cardiovascular & Thoracic Surgery
Slaughter, Mark	Cardiovascular & Thoracic Surgery
Wu, Jon	Cardiovascular & Thoracic Surgery
Berson, Eric	Chemical Engineering
Fried, Joel	Chemical Engineering
Fu, Sean	Chemical Engineering
Kang, Kyung	Chemical Engineering
Demuth, Don	Dentistry – Oral Health & Rehab
Amini, Amir	Electrical & Computer Engineering
Cohn, Bob	Electrical & Computer Engineering
Harnett, Cindy	Electrical & Computer Engineering
Naber, John	Electrical & Computer Engineering
Walsh, Kevin	Electrical & Computer Engineering
Sharp, Keith	Mechanical Engineering
Williams, Stuart J.	Mechanical Engineering
Miller, Donald	Medicine & Pharmacology
Buning, Mary Ellen	Neurological Surgery
Behrman, Andrea	Neurological Surgery
Harkema, Susan	Neurological Surgery
Howland, Dena	Neurological Surgery
Magnuson, David	Neurological Surgery
Ovechkin, Alex	Neurological Surgery
Whittemore, Scott	Neurological Surgery
Joshua, Irving	Physiology & Biophysics
Kang, James	Physiology & Biophysics

Appendix B

Letters of Support

UNIVERSITY OF
LOUISVILLE.
It's Happening Here.

School of Interdisciplinary and Graduate Studies
University of Louisville
2211 S. Brook Street
Louisville, KY 40292

November 16, 2015

Robert S. Keynton, Ph.D.
Professor and Lutz Endowed Chair of Biomechanical Devices
Department of Bioengineering
University of Louisville
Louisville, KY 40292

Dear Dr. Keynton.

This letter is to confirm the commitment by the School of Interdisciplinary and Graduate Studies (SIGS) to provide resources to support the proposed new Doctoral Program in Interdisciplinary Studies: Specialization in Translational Bioengineering. Specifically, SIGS will commit a maximum of four (4) fellowship lines to be funded at any one time, for the first 5 years of the program. These fellowships include an annual stipend of $22,000, health insurance and full tuition. In addition, SIGS will fund 0.1 FTE of an administrative assistant who will provide administrative support for the degree program.

I am pleased that we are able to support this exciting new interdisciplinary program, and I appreciate the hard work that you and the rest of the steering committee have put into development of this degree. We look forward to working with you and the faculty of this new program as you recruit the program's first cohort of students.

Sincerely,

Beth A. Boehm

Cc: Paul DeMarco, Ph.D., Associate Dean, SIGS

UNIVERSITY OF
LOUISVILLE.
COLLEGE OF BUSINESS

DATE: October 8, 2015

RE: Proposed Doctoral Program in Translational Bioengineering

TO: Beth Boehm, Ph.D.
Dean, School of Interdisciplinary and Graduate Studies

Faculty of the Entrepreneurship Department and my office have reviewed the Doctor of Philosophy Degree in Interdisciplinary Studies with a Specialization in Translational Bioengineering (ISSTBE) proposal. We are in support of this program and will work with interested faculty in the College of Business allowing them to serve as co-mentors or dissertation committee members.

We will also permit ISSTBE students to enroll in courses within the Entrepreneurship Department that are listed in the proposal, provided students satisfy necessary prerequisites. We look forward to working with the School of Interdisciplinary and Graduate Studies to provide students with this unique Translational Bioengineering education and training opportunity.

Sincerely,

Dr. Rohan Christie-David
Professor & Interim Dean
College of Business

cc: Gina Bertocci, PhD
Robert Keynton, PhD

University of Louisville • College of Business • Louisville, KY 40292
P: 502.852.6440 **F:** 502.852.7557 **W:** louisville.edu/business

UNIVERSITY OF
LOUISVILLE.
SCHOOL OF DENTISTRY

Office of the Dean

26 June, 2015

Dr Robert Keynton, PhD
Chair, Department of Bioengineering
Speed School of Engineering

Dear Dr. Bob,

This letter is in support of the proposal to SIGS for a new Interdisciplinary PhD program titled: **Doctoral Program in Interdisciplinary Studies: Specialization in Translational Bioengineering**. When I heard about this program I was excited to finally see much of what we have previously discussed evolve. I am convinced that there are phenomenal opportunities for both innovation and discovery in such this program. I most certainly support the establishment of this program, and will actively encourage the participation of ULSD faculty in advising and mentoring these students. I approve of students in this program enrolling in the Oral Biology courses which are part of the graduate programs in ULSD.

Dentistry as a field has been weak on innovation to develop novel therapies. This program will train students to address these issues by its focus on translational bioengineering. I expect that collectively students and faculty will benefit from these interactions.

Warmest regards,

John J. Sauk, D.D.S.
Professor & Dean

School of Dentistry • Office of the Dean • 501 South Preston Street • Room 240 • Louisville, KY 40202
P: 502.852.5295 **F:** 502.852.3364 **W:** louisville.edu/dental

UNIVERSITY OF LOUISVILLE

Department of Oral Immunology & Infectious Diseases

June 25, 2015

Dr. Robert Keynton, PhD
Chair, Department of Bioengineering
Speed School of Engineering
University of Louisville

Dear Dr. Keynton,

I am enthusiastic to have the School of Dentistry participate in the proposed new PhD program titled: **Doctoral Program in Interdisciplinary Studies: Specialization in Translational Bioengineering**. This program will allow students with a strong interest in translational bioengineering to interact and be mentored by faculty and residents involved with delivering oral health care to patients. As Director of the Oral Biology Graduate Program, I support these students having the opportunity to enroll in our Oral Biology classes, providing them with a strong background in the biological basis for clinical oral biology. I have spoken with several directors of dental residency programs, and each has been open to having PhD students shadow in their clinics.

This program will enhance collaboration between the faculty in the School of Dentistry and the Bioengineering Department. To date we have several Masters in Oral Biology students who work on projects involving both Speed School and ULSD, demonstrating the interest of the faculty to collaborate. The proposed PhD track will open the possibilities for larger and longer-term projects, and more in-depth interactions between the schools.

Best regards,

Douglas Darling

Douglas S. Darling, PhD
Professor
Director, Oral Biology Graduate Program

School of Dentistry, 501 South Preston Street, Room 320, Louisville, KY 40292
Phone: (502) 852-5508

UNIVERSITY OF
LOUISVILLE.
SCHOOL OF MEDICINE

Toni M. Ganzel, MD, MBA
Dean of the School of Medicine
Professor of Otolaryngology

October 13, 2015

Beth Boehm, Ph.D.
Dean
School of Interdisciplinary and Graduate Studies
University of Louisville

Dear Dr. Boehm,

As Dean of the School of Medicine, I have reviewed the Doctor of Philosophy Degree in Interdisciplinary Studies with a Specialization in Translational Bioengineering (ISSTBE) proposal and I fully support ISSTBE students enrolling in courses offered within the School of Medicine, provided students satisfy all necessary prerequisites.

In addition, I also support our School of Medicine faculty serving as co-mentors or dissertation committee members for ISSTBE students.

I'm excited about this endeavor and look forward to hearing more about the success of our students and the wonderful training opportunities provided within the Translational Bioengineering education program.

Best of luck!

Sincerely,

Toni M. Ganzel

Toni M. Ganzel, M.D., M.B.A.
Dean

cc: Gina Bertocci, Ph.D.
Robert Keynton, Ph.D.

University of Louisville • Abell Administration Center • 323 East Chestnut Street • Louisville, KY 40202-1823
P: 502.852.1499 **F:** 502.852.1484 **W:** louisville.edu/medschool

UNIVERSITY OF LOUISVILLE
J.B. SPEED SCHOOL OF ENGINEERING

Office of the Dean

October 15, 2015

Dr. Robert Keynton
Chair, Department of Bioengineering
University of Louisville
Louisville, KY 40292

Dear Rob:

It is with great enthusiasm that I am writing in full support of the Doctor of Philosophy Degree in Interdisciplinary Studies with Specialization in Translational Bioengineering (ISSTBE). Key constituents within the JB Speed School of Engineering, including faculty, department chairs and I, have reviewed the proposal and are supportive of ISSTBE students enrolling in our engineering courses. In addition, our faculty are committed to working with ISSTBE students to serve as mentors and dissertation advisors.

This program will create excellent opportunities for collaborations within the current academic and research programs in the schools of engineering, medicine, dentistry, business and more. I especially look for the ISSTBE PhD students to work closely with our engineering faculty to apply their expertise and talents to further enhance our level of innovation and find creative new ways to better engineer human health. The overall outcomes of the program will certainly yield tremendous benefits to the students and faculty, and also to the university as a whole.

I look forward to working with the School for Interdisciplinary and Graduate Studies to assist in any way I can to make sure the program is successful. Best of luck as this moves forward!

Sincerely,

John S. Usher, PhD
Acting Dean

UNIVERSITY OF
LOUISVILLE.

FORCHT CENTER FOR
ENTREPRENEURSHIP

DATE: October 8, 2015

RE: Proposed Doctoral Program in Translational Bioengineering

TO: Beth Boehm, Ph.D.
Dean, School of Interdisciplinary and Graduate Studies

Faculty of the Entrepreneurship Department have reviewed the Doctor of Philosophy Degree in Interdisciplinary Studies with a Specialization in Translational Bioengineering (ISSTBE) proposal. We are in support of this program and will work with interested faculty in our department allowing them to serve as co-mentors or dissertation committee members.

We will also permit ISSTBE students to enroll in courses within our department that are listed in the proposal, provided students satisfy necessary prerequisites. We look forward to working with the School of Interdisciplinary and Graduate Studies to provide students with this unique Translational Bioengineering education and training opportunity.

Sincerely,

Van G.H. Clouse

Dr. Van G.H. Clouse
Chair and Associate Professor
Entrepreneurship Department
College of Business

cc: Gina Bertocci, PhD
Robert Keynton, PhD

UNIVERSITY OF
LOUISVILLE
SCHOOL OF DENTISTRY

Office of Postgraduate Education

June 29, 2015

Robert Keynton, PhD
Chair, Department of Bioengineering
Speed School of Engineering

Dear Dr. Keynton,

This letter is in support of the proposal to SIGS for a new Interdisciplinary PhD program titled: **Doctoral Program in Interdisciplinary Studies: Specialization in Translational Bioengineering**. This is a strongly interdisciplinary program involving the Speed School and Dental School, as well as the Schools of Medicine and Business. The focus is to give students a background in both clinical sciences and bioengineering to support those who will be innovative entrepreneurs addressing current hurdles to delivery of health care. This program was strongly supported at a recent meeting of the Dental School Dean's Administrative Staff.

As the Associate Dean for Postgraduate Education within the School of Dentistry, I am enthusiastic about giving our students and faculty the opportunity to work in depth with students and faculty from the Bioengineering Department. I support having students in this interdisciplinary doctoral program participate in OBIO courses and shadowing here in the School of Dentistry. I certainly hope that this program will enhance collaboration between the faculty in these schools.

Sincerely,

Margaret Hill, DMD
Associate Dean for Postgraduate Education

University of Louisville • School of Dentistry • Louisville, KY 40292
P: 502.852.0002 **F:** 502.852.1317 **W:** louisville.edu/dental

UNIVERSITY OF LOUISVILLE
SCHOOL OF MEDICINE

William Guido, Ph.D.
Office of the Chair
Department of Anatomical Sciences and Neurobiology
511 S. Floyd Street
Louisville, KY 40202
P: 502.852.6227
F: 502.852.6228
E: william.guido@louisville.edu
http://louisville.edu/medschool/anatomy

DATE: June 30, 2015

RE: Proposed Doctoral Program in Translational Bioengineering

TO: Beth Boehm, Ph.D.
Dean, School of Interdisciplinary and Graduate Studies

Dear Dr. Boehm

The Department of Anatomical Sciences and Neurobiology has reviewed the Doctor of Philosophy Degree in Interdisciplinary Studies with a Specialization in Translational Bioengineering (ISSTBE) proposal. We are in support of this program and will permit ISSTBE students to enroll in courses within our department that are listed in the proposal, provided students satisfy necessary prerequisites. We look forward to working with the School of Interdisciplinary and Graduate Studies to provide students with this unique Translational Bioengineering education and training opportunity.

Sincerely,
William Guido

William Guido, PhD
Professor and Chair, ASNB

cc: Gina Bertocci, PhD
Robert Keynton, PhD

UNIVERSITY OF LOUISVILLE

Biochemistry and Molecular Biology

DATE: June 30, 2015

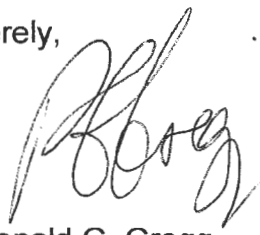
RE: Proposed Doctoral Program in Translational Bioengineering

TO: Beth Boehm, Ph.D.
Dean, School of Interdisciplinary and Graduate Studies

Faculty of the Department of Biochemistry and Molecular Biology, School of Medicine have reviewed the Doctor of Philosophy Degree in Interdisciplinary Studies with a Specialization in Translational Bioengineering (ISSTBE) proposal. We are in support of this program and will work with interested faculty in our department allowing them to serve as co-mentors or dissertation committee members.

We will also permit ISSTBE students to enroll in courses within our department that are listed in the proposal, provided students satisfy necessary prerequisites. We look forward to working with the School of Interdisciplinary and Graduate Studies to provide students with this unique Translational Bioengineering education and training opportunity.

Sincerely,



Dr. Ronald G. Gregg
Chair and Professor
Department of Biochemistry and Molecular Biology
School of Medicine

cc: Gina Bertocci, PhD
Robert Keynton, PhD

University of Louisville • School of Medicine • Louisville, KY 40292
P: 502.852.5213 **F:** 502.852.6222 **W:** louisville.edu/medschool

June 8, 2015

Robert S. Keynton, PhD
Chair and Professor
Lutz Endowed Chair of Biomechanical Devices
Department of Bioengineering (A Wallace H. Coulter Foundation Partner)

Gina Bertocci, PhD, PE
Professor
Endowed Chair, Biomechanics
Department of Bioengineering (A Wallace H. Coulter Foundation Partner)

Dear Drs. Keynton and Bertocci,

It was a pleasure meeting today and discussing your vision for the Interdisciplinary Translational Bioengineering PhD program partnership, with the plan of enrolling the first students in the program this fall. We are happy to write this letter of support for this new program and look forward to working with you.

At our meeting, we discussed the timing and feasibility of a required 3-credit course involving a clinical shadowing experience for your students within our clinical educational sites. You wish for your students to experience physician interaction in the clinical setting as an inspiration for their scholarly work in the program as well as an introduction to the communication and problem-solving strategies used by clinicians on overcoming practical obstacles encountered in care. We agree this is very valuable and are excited to help you develop this aspect of your program.

We discussed the time necessary to spend on service for a student to receive 3 credit hours. While your group is still determining the final number of hours, an overall goal of 35-40 hours spent in the clinical environment seemed appropriate and was discussed as a goal. We also discussed timing of the clinical experience. You anticipate this will fall at the end of the second year of your program. On our end, it is preferable to have this shadowing occur in May or June, as our 4th year medical students have graduated and fewer learners will be on each team, making room for your students. Your estimate of the number of students/year is about 3-5. We believe this number of students can be accommodated and will receive an excellent clinical shadowing experience.

We discussed some details of the clinical experience for these students, and how site assignment and credentialing would occur. At this time, it is most useful to

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P: 502.852.8695 **F:** 502.852.2368

keep the possible sites that can be used open and flexible based on the needs of the particular student. We agree to work with you to provide great educational placements for your students.

To facilitate proper student placement, you plan to notify us of the number of students who need placement and their identified area of clinical interest (if they have one) in February of the year the student will need to be scheduled. We will work with you and our clinical teaching chiefs to identify and confirm spots for these students, and after spots are confirmed they can register officially in March/April as part of the summer registration process. We will also help you identify what additional training or certification the student will need according to their assigned site. It is understood the students' roles will be as a clinical shadower/observer only, and it is also understood that your students will have already completed HIPAA training by the time they start this course.

An additional detail we did not discuss today is that our clinical teachers will need to be given the syllabus for the course and the responsible faculty to contact regarding the student. Please send that syllabus when you communicate regarding the number of students that need to be placed, as we would like to ensure the placement is suitable for fulfilling the requirements of the course.

Many thanks for your innovation in developing this new interdisciplinary program! You are making our university a better place to work and learn, and sparking future innovations to help our patients and community!

Sincerely,

Monica Ann Shaw, MD, MA, FACP
Senior Associate Dean for Medical Education
Professor of Medicine

Amy L. Holthouser, MD
Associate Dean for Medical Education
Associate Professor of Medicine and Pediatrics

UNIVERSITY of LOUISVILLE
dare to be great

DEPARTMENT OF MICROBIOLOGY AND IMMUNOLOGY

School of Medicine
University of Louisville
Louisville, Kentucky 40292
Office: 502-852-5351
Fax: 502-852-7531

DATE: July 17, 2015

RE: Proposed Doctoral Program in Translational Bioengineering

TO: Beth Boehm, Ph.D.
Dean, School of Interdisciplinary and Graduate Studies

Faculty of the Department of Microbiology and Immunology, School of Medicine have reviewed the Doctor of Philosophy Degree in Interdisciplinary Studies with a Specialization in Translational Bioengineering (ISSTBE) proposal. We are in support of this program and will permit ISSTBE students to enroll in courses within our department that are listed in the proposal, provided students satisfy necessary prerequisites. We look forward to working with the School of Interdisciplinary and Graduate Studies to provide students with this unique Translational Bioengineering education and training opportunity.

Sincerely,

Nejat Egilmez, Ph.D.
Professor and Chairman
Department of Microbiology and Immunology
School of Medicine

cc: Gina Bertocci, PhD
Robert Keynton, PhD

UNIVERSITY OF LOUISVILLE
SCHOOL OF MEDICINE

Department of Neurological Surgery

DATE: June 30, 2015

RE: Proposed Doctoral Program in Translational Bioengineering

TO: Beth Boehm, Ph.D.
Dean, School of Interdisciplinary and Graduate Studies

Faculty of the Department of Neurological Surgery, School of Medicine have reviewed the Doctor of Philosophy Degree in Interdisciplinary Studies with a Specialization in Translational Bioengineering (ISSTBE) proposal. We are in support of this program and will work with interested faculty in our department allowing them to serve as co-mentors or dissertation committee members.

We will also permit ISSTBE students to enroll in courses within our department that are listed in the proposal, provided students satisfy necessary prerequisites. We look forward to working with the School of Interdisciplinary and Graduate Studies to provide students with this unique Translational Bioengineering education and training opportunity.

Sincerely,

Dr. Warren Boling
Chair and Professor
Department of Neurological Surgery
School of Medicine

cc: Gina Bertocci, PhD
Robert Keynton, PhD

220 Abraham Flexner Way, 15th Floor ● University of Louisville ● Louisville, KY 40202
P: 502.407.3226 **F:** 502.582.7477

UNIVERSITY OF LOUISVILLE®

Peter K. Knoefel Endowed Chair of Pharmacology & Toxicology
Professor and Chair, Department of Pharmacology & Toxicology
Associate University Provost for Strategic Planning
Distinguished University Scholar

David W. Hein, PhD
Kosair Charities CTR - Room 303
University of Louisville Health Sciences Center
505 South Hancock Street
Louisville, Kentucky 40202-1617

Phone: 502-852-6252
Email: d.hein@louisville.edu
Website: www.louisville.edu/faculty/dwhein01

August 18, 2015

Beth Boehm, Ph.D.
Dean, School of Interdisciplinary and Graduate Studies

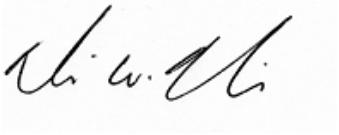
RE: Proposed Doctoral Program in Translational Bioengineering

Dear Beth,

The course directors for Department of Pharmacology and Toxicology courses listed as electives in the Doctor of Philosophy Degree in Interdisciplinary Studies with a Specialization in Translational Bioengineering (ISSTBE) proposal have expressed no concerns about including these courses as electives. Therefore, we will permit ISSTBE students to enroll in courses within our department that are listed in the proposal, provided students satisfy necessary prerequisites. We are in support of this program and will work with interested faculty in our department allowing them to serve as co-mentors or dissertation committee members.

We look forward to working with the School of Interdisciplinary and Graduate Studies to provide students with this unique Translational Bioengineering education and training opportunity.

Sincerely,



David W. Hein
Peter K. Knoefel Chair

cc: Gina Bertocci, PhD
Robert Keynton, PhD
J. Christopher States, PhD

UNIVERSITY OF LOUISVILLE
SCHOOL OF MEDICINE

Irving G. Joshua, Ph.D.
Professor and Chairman
Department of Physiology and Biophysics

DATE: August 17, 2015

RE: Proposed Doctoral Program in Translational Bioengineering

TO: Beth Boehm, Ph.D.
Dean, School of Interdisciplinary and Graduate Studies

Faculty of the Department of Physiology in the School of Medicine have reviewed the Doctor of Philosophy Degree in Interdisciplinary Studies with a Specialization in Translational Bioengineering (ISSTBE) proposal. We are in support of this program and will work with interested faculty in our department allowing them to serve as co-mentors or dissertation committee members.

We will also permit ISSTBE students to enroll in courses within our department that are listed in the proposal, provided students satisfy necessary prerequisites. We look forward to working with the School of Interdisciplinary and Graduate Studies to provide students with this unique Translational Bioengineering education and training opportunity.

Sincerely,

Irving G. Joshua, Ph.D.
Chairman, Department of Physiology

cc: Gina Bertocci, Ph.D.
Robert Keynton, Ph.D.

University of Louisville • Health Sciences Center, A-1115 • 500 S. Preston Street • Louisville, KY 40202
P: 502.852.5371 **F:** 502.852.6239 **E:** igjosh01@louisville.edu **W:** louisville.edu/medicine

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J.B. SPEED SCHOOL
OF ENGINEERING

Department of Chemical Engineering

DATE: August 25, 2015

RE: Proposed Doctoral Program in Translational Bioengineering

TO: Beth Boehm, Ph.D.
Dean, School of Interdisciplinary and Graduate Studies

Faculty of the Department of Chemical Engineering have reviewed the Doctor of Philosophy Degree in Interdisciplinary Studies with a Specialization in Translational Bioengineering (ISSTBE) proposal. We are in support of this program and will work with interested faculty in our department allowing them to serve as co-mentors or dissertation committee members.

We will also permit ISSTBE students to enroll in courses within our department that are listed in the proposal, provided students satisfy necessary prerequisites. We look forward to working with the School of Interdisciplinary and Graduate Studies to provide students with this unique Translational Bioengineering education and training opportunity.

Sincerely,

Joel R. Fried
Professor and Chair

cc: Gina Bertocci, PhD
Robert Keynton, PhD

University of Louisville • Louisville, KY 40292
P: 502.852.6347 **F:** 502.852.6355 **W:** louisville.edu/speed

UNIVERSITY OF LOUISVILLE
J.B. SPEED SCHOOL OF ENGINEERING

Computer Engineering and Computer Science
Duthie Center for Engineering
University of Louisville
Louisville, KY 40292

DATE: August 27, 2015

RE: Proposed Doctoral Program in Translational Bioengineering

TO: Beth Boehm, Ph.D.
Dean, School of Interdisciplinary and Graduate Studies

The Computer Engineering and Computer Science Department have reviewed the Doctor of Philosophy Degree in Interdisciplinary Studies with a Specialization in Translational Bioengineering (ISSTBE) proposal. We are in support of this program and will work with interested faculty in our department allowing them to serve as co-mentors or dissertation committee members.

We will also permit ISSTBE students to enroll in courses within our department that are listed in the proposal when offered, provided students satisfy necessary prerequisites. We look forward to working with the School of Interdisciplinary and Graduate Studies to provide students with this unique Translational Bioengineering education and training opportunity.

Sincerely,

Dr. Adel Elmaghraby
Professor and Department Chair
adel@louisville.edu

Department of Electrical and Computer Engineering

UNIVERSITY OF LOUISVILLE
It's Happening Here.

DATE: August 27, 2015

RE: Proposed Doctoral Program in Translational Bioengineering

TO: Beth Boehm, Ph.D.
Dean, School of Interdisciplinary and Graduate Studies

As Chair of the Department of Electrical and Computer Engineering, I have reviewed the Doctor of Philosophy Degree in Interdisciplinary Studies with a Specialization in Translational Bioengineering (ISSTBE) proposal. I am in support of this program and will work with interested faculty in our department allowing them to serve as co-mentors or dissertation committee members.

I will also permit ISSTBE students to enroll in courses within our department that are listed in the proposal, provided students satisfy necessary prerequisites, and cleanroom usage fees are provided as needed. I look forward to working with the School of Interdisciplinary and Graduate Studies to provide students with this unique Translational Bioengineering education and training opportunity.

Sincerely,

Bruce Alphenaar

Professor and Chairman
Electrical and Computer Engineering

Email:brucea@louisville.edu
502/852-1554

cc: Gina Bertocci, PhD
Robert Keynton, PhD

UNIVERSITY OF LOUISVILLE
J.B. SPEED SCHOOL OF ENGINEERING

Department of Industrial Engineering

DATE: August 22, 2015

RE: Proposed Doctoral Program in Translational Bioengineering

TO: Beth Boehm, Ph.D.
Dean, School of Interdisciplinary and Graduate Studies

Faculty of the Industrial Engineering Department have reviewed the Doctor of Philosophy Degree in Interdisciplinary Studies with a Specialization in Translational Bioengineering (ISSTBE) proposal. We are in support of this program and will work with interested faculty in our department allowing them to serve as co-mentors or dissertation committee members.

We will also permit ISSTBE students to enroll in courses within our department that are listed in the proposal, provided students satisfy necessary prerequisites. We look forward to working with the School of Interdisciplinary and Graduate Studies to provide students with this unique Translational Bioengineering education and training opportunity.

Sincerely,

Suraj M. Alexander, Ph.D., P.E.
Professor and Chairman

cc: Gina Bertocci, PhD
Robert Keynton, PhD

University of Louisville•Louisville, KY 40292
P: 502.852.6342 **F**: 502-852-5633 **W**:louisville.edu/speed/industrial

UNIVERSITY OF LOUISVILLE

DEPARTMENT OF MECHANICAL ENGINEERING
J.B. Speed School of Engineering
University of Louisville
Louisville, KY 40292

Office: 502-852-6331
Fax: 502-852-6053

DATE: September 3, 2015

RE: Proposed Doctoral Program in Translational Bioengineering

TO: Beth Boehm, Ph.D.
Dean, School of Interdisciplinary and Graduate Studies

As the chairman of the Mechanical Engineering (M.E.) Department, I have carefully reviewed the proposed Doctor of Philosophy Degree in Interdisciplinary Studies with a Specialization in Translational Bioengineering (ISSTBE). I support the development and implementation of this Ph.D. program, as it spans degree programs and promises to promote interdisciplinary research. This is a novel and worthwhile endeavor. I support this with the understanding that should any of the M.E. courses that make up the core course requirements not be offered or be eliminated altogether, the ISSTBE program will be responsible for adapting program requirements appropriately; the M.E. department will not be responsible for any implications to the ISSBE program if a course is not offered or eliminated.

I have shared this proposal with our faculty via email. Our first opportunity to discuss this as a group will be in our first faculty meeting of the academic year, which is scheduled for Thursday, September 10. The ISSTBE program is a prominent agenda item on the schedule.

Again, I support the Ph.D. program in ISSTBE and hope it is adopted. I believe it will serve the university well to have such a distinctive, forward-looking program.

With best regards,

Kevin D. Murphy, Professor and Chairman
Department of Mechanical Engineering

cc: Gina Bertocci, Ph.D.
Robert Keynton, Ph.D.

UNIVERSITY OF
LOUISVILLE
UNIVERSITY LIBRARIES

July 2, 2015

Connie Shumake
Office of the Provost
University of Louisville
Louisville, KY 40292

Connie,

We have been asked to provide a description of the library resources in place to support the proposed SIGS Interdisciplinary PhD program in Translational Bioengineering. Ekstrom Library has prepared an analysis of our ability to support the new program and this review indicates that our journal holdings seem more than adequate to support the proposed program but that our current monographic holdings in subject areas relevant to the proposed program are very low in comparison to two of our benchmarks with similar programs. I'm attaching the analysis and description of available library and information resources which includes books, journals and indexes. Many of the resources are accessible 24/7 from on campus or from home as they are in electronic format.

Additional library expenditures will be required to support the program if faculty request a stronger monograph collection.

Please contact us if you have any questions or need additional information.

Sincerely,

Robert E. Fox, Jr.
Dean, University Libraries

Cc: Robert Keynton
Bruce Keisling
James Manasco

Appendix C

Course Descriptions

ASNB 602 Fundamentals of Neuroscience
Description: Basics of cellular and systems neuroscience are taught through a combination of lectures, laboratories, and independent study. Lectures concurrent with ASNB 502; one added lecture hour each week covers advanced topics through recent article readings and discussion. Topics covered include: electrical potentials in the nervous system, synaptic transmission, somatosensory pathways, special senses (vision, hearing, balance, taste and smell), eye movements, motor systems, and higher functions (language, sleep and wakefulness, cognition, emotion and memory). Credit may not be earned for both ASNB 502 and 602.

ASNB 614 Molecular Neurobiology
Description: Prerequisite: Consent of instructor. Structure and function of the nervous system from a molecular perspective. Includes description of membrane proteins, channels and receptors in neurons and glia. Discussion of the role of such molecular structures in the nervous system.

ASNB 617 Developmental Neurobiology
Description: Prerequisite: ASNB 615 or consent of instructor. Covers neural development from neurulation through development of integrated systems. Emphasis will be on the cellular level.

BE 600 Modeling of Biological Phenomena
Description: Prerequisite: Graduate/Professional Standing in Bioenginering or Consent of Instructor. An advanced course in bioengineering topics not covered by regularly scheduled courses.

BE 601 Bioengineering Seminar
Description: Current research topics in the field of translational bioengineering will be presented and discussed. Sessions will include guest speakers, student presentations on research projects with interaction and feedback from students and faculty, and critical discussion of scientific literature.

BE 603 Research Ethics in Bioengineering
Description: Complex ethical issues facing bioengineers will be addressed, including conflicts of interest, patient rights, protection, beneficence and confidentiality, equitable allocation of scarce health resources, research misconduct, animal experimentation, and clinical trials for new medical devices.

BE 605 Tissue and Molecular Biology Techniques
Description: Prerequisite: BE 452 or BE 453. Introduces students to techniques used in tissue and molecular Biology laboratories including cell and tissue culture, cell assays, cell and tissue imaging techniques, sterilization techniques, capillary electrophoresis and western blotting.

BE 611 Cardiovascular Dynamics I
Description: Prerequisite: Graduate/professional standing in bioengineering. Pre- or Co-Requisite: BE 621. Review basic cardiovascular physiology. Application of basic engineering principles, including electrical and mechanical analog models to describe cardiovascular function and data acquisition and analysis techniques to develop medical devices and instrumentation.

BE 639 Injury Biomechanics
Description: Prerequisite: ME 649 or BE 354 or equivalent, or permission of the instructor. Note: Crosslisted with ME 639. Application of mechanics to the study of human injury. Response of the human body to injurious

conditions. Injury tolerance of the human body. Applications to child abuse, transportation safety and the medico-legal environment.

BE 640 Computational Methods for Medical Image Analysis
Description: Prerequisite: BE 420. This course covers the theory of stochastic and geometric models of medical imaging, including spatial interaction models, intensity models, and geometric shape models. The emphasis is on understanding the underlying mathematics in a practical sense.

BE 650 Advanced Biomaterials
Description: Prerequisite: BE 450 or consent of instructor. Advanced topics on the use of biomaterials, and their performance, in reconstructive surgery. Specifically skin, nerve, bone, and soft tissue regeneration utilized for burn patients, cancer patients, and trauma patients.

BE 653 Nanoscale Bioengineering
Description: Prerequisite: BE 453. Discuss the approaches and techniques in designing, building, characterizing and using biomedical applications, including, interrogation of cellular systems, drug delivery systems, therapeutic systems and uses in tissue engineering applications.

BE 658 Rehabilitation Engineering and Assistive Technology
Description: Prerequisite: ME 649 or BE 354 or equivalent or permission of instructor. Note : Crosslisted with ME 658. Introduction to rehabilitation engineering and assistive technology. Medical aspects of disability, assistive technology applications and current rehabilitation research.

BE 668 Teaching Practicum
Description: A guided learning experience in inquiry-based instructional techniques and best practices in engineering education that includes field experience as a graduate instructor.

BE 680 Bio- Micro- Electro- Mechanical Systems
Description: Prerequisite: Graduate/professional standing and ECE 543 or instructor's permission. Application of microtechnology principles to the biomedical field in areas that include tissue engineering, lab-on-a-chip, biosensors, drug delivery, etc. Application-specific criteria supporting the need for miniaturization.

BE 683 Artificial Organs
Description: Prerequisite: Graduate/professional standing in bioengineeing and BE 450. Bioengineering design of artificial organ replacement systems and their clinical usage. Commercially available systems analyzed for mass transfer efficiency; biomechanics and hemodynamics; and size and efficiency of the device.

BE 692 Clinical Rotation
Description: Pre-requisites: Successful completion of the Qualifying Exam and current HIPAA training certificate. Approval from student's PhD advisor and Director of PhD in Interdisciplinary Studies with Specialization in Translational Bioengineering Program required. Co-requisite: Students must obtain necessary hospital/healthcare facility credentialing prior to beginning clinical rotation. Students will observe day-to-day clinical activities associated with patient care by participating in clinical rounds and/or scheduled specialty clinics led by residents, fellows and/or clinical faculty. Exposure to the clinical setting will allow students to gain an understanding of concepts such as patient history, disorder/disease presentation, diagnostics, clinical

decision making, treatment modalities, disease management, procedures and clinical outcomes. The Bioengineering Clinical Rotation can be conducted within either the School of Medicine or School of Dentistry.

BE 693 Independent Study in Bioengineering
Description: Prerequisite: Faculty consent. An advanced theoretical or experimental investigation of a problem area related to Bioengineering.

BE 695 Advanced Research Design and Methods
Description: Topics include the structure of scientific journal papers and proposals, development of specific aims, formulation of hypotheses, types of study design/research methodologies and their appropriate application, data management, data analysis strategies, interpretation and communication of research findings, critique of the scientific literature, and responsible conduct in research.

BE 696 Evidence Based Entrepreneurship
Description: Intensive training and application of the Lean LaunchPad methodology and business model to identify building blocks that constitute a successful business. Agile development principles will be used to rapidly iterate a product or concept to build/design something customers will buy and use. Students will be required to spend time each week outside of class conducting interviews and updating their business model for presentation throughout the course.

BE 699 Dissertation Research
Description: Original research activity in an appropriate translational bioengineering discipline, under the direction of a graduate faculty member affiliated with PhD in Interdisciplinary Studies with a Specialization in Translational Bioengineering (ISSTBE-PhD).

BIOC 645 Advanced Biochemistry
Description: Prerequisite: Organic Chemistry II (CHEM 342). Note: Cross-listed with CHEM 645. Chemistry of amino acids, peptides, proteins, nucleotides and nucleic acids; methods of analysis and laboratory synthesis; nucleotides; RNA, DNA and protein biosynthesis. Lectures concurrent with CHEM 545; one added lecture hour each week covers advanced topics. Credit may not be earned in both 545 and 645.

BIOC 680 Biomolecular Interactions
Description: Prerequisite: BIOC 645 and BIOC 647 or equivalents. This course examines techniques used to characterize biomolecules and their interactions including surface plasmon resonance, equilibrium dialysis, microcalorimetry, analytical ultracentrifugation, dynamic light scattering and absorption fluorescence and circular dichroism spectroscopies.

BIOC 668 Molecular Biology
Description: Prerequisite: BIOC 645 and 647, or consent of instructor. Note: Cross-listed with BIOL 668. Molecular aspects of the structure and function of cells with emphasis on mechanisms and regulation of gene expression.

BIOC 611 Biochemical and Molecular Methods
Description: Prerequisite: Concurrent BIOC 645 or equivalent. An introduction to modern biochemical and molecular biology methods in lecture and laboratory format. Methods covered include RNA isolation,

preparative and cytpnockownsquantitative PCR, cloning and sequencing, transfection and reporter gene analysis, western bolts, use of siRNA okdowns, cytiommunoflourescence, and enzyme characterization.

CECS 622 Simulation and Modeling of Discrete Systems
Description: Prerequisite: Probability & Statistics for Engineers (IE 360). Engineering design of simulation languages and simulators, discrete stochastic systems, issues in large scale simulation studies and engineering evaluation methods.

CECS 624 Advanced Simulation
Description: Selected advanced topics in computer and software architectures, algorithms and models in simulation.

CECS 627 Digital Image Processing
Description: Prerequisite: CECS 506 or ECE 420 or faculty consent. A course that surveys basic concepts in image processing and pattern recognition. Topics included are: contrast and edge enhancement, histogram modification, image segmentation, feature extraction, statistical classifiers. Design problems involving computer implementation of algorithms are used extensively.

CECS 628 Computer Graphics
Description: Prerequisite: CECS 302. This course presents an introduction to computer graphics hardware and interactive engineering computer graphics techniques. Topics include engineering computer- aided design, graphics hardware (display processors and displays, hardcopy output devices, input devices), graphics standards and graphical kernel system, graphic object representation and transformation, interaction techniques, and three-dimensional graphics. Hardware graphics options are discussed and used.

CECS 633 Computer Vision
Description: Review of elementary pattern recognition and image processing; extension to advanced topics in computer vision, such as three-dimensional vision and perception, syntactic pattern recognition, motion, texture and color vision applications.

CECS 660 Introduction to Bioinformatics
Description: Prerequisite: CECS 302 or CECS 503. Covers the current state of the art programs designed for sequence alignment, database searching, RNA structure prediction, microarray, sequence analysis, gene prediction, repeat detection, and protein folding prediction. A detailed analysis of the algorithms behind each of these will be explored. The algorithmic techniques discussed will include dynamic programming, hidden Markov models, finite state automata, grammars, Karlin-Altschul statistics and Bayesian statistics.

ECE 520 Digital Signal Processing
Description: Prerequisite: Signals & Linear Systems (ECE 420). Co-requisite: ECE 521. Discrete time signals and systems; Discrete Fourier Transforms, FFT algorithms, flow graph and the matrix representation of digital filters; FIR and IIR filter design techniques; quantization effects; spectral estimation; current applications of digital signal processing.

ECE 521 Digital Signal Processing Laboratory
Description: Prerequisite: Signals & Linear Systems (ECE 420). Co-requisite: ECE 520. Focuses on the implementation of common digital signal processing functions using state-of-the-art DSP devices and

software. Introduction to fundamentals of discrete-time signal processing and digital signal processor architectures and applications. Emphasis on laboratory experience involving generation of deterministic and random signals; digital filter design; quantization effects; FFT computation; linear system analysis; speech processing.

ECE 523 Introduction to Biometrics
Description: Prerequisite: ECE 420 and senior standing. Biometric approaches aim at identification based on a physical characteristic. Survey of biometric techniques with focus on non-intrusive approaches. Topics covered include image formation, sensors, motion tracking, and face recognition algorithms.

ECE 543 Micro-fabrication and MEMS
Description: Prerequisite: Senior Standing. Microfabrication techniques including cleanroom technology, lithography, thermal oxidation, diffusion, ion implantation, film deposition, etching, micromachining, wafer-level bonding/polishing, and packaging yield. Microtechnology measurement and analysis techniques. Process simulation. CAD device-layout. MEMS (microelectromechanical systems) and microelectric technology and applications. Material issues for MEMS/microelectronics.

ECE 544 Micro-fabrication and MEMS Laboratory
Description: Prerequisite/Co-requisite: ECE 543. Laboratory to illustrate microfabrication processes, semiconductor measurement techniques, MEMS microstructure fabrication, and MEMS testing. Cleanroom activity required.

ECE 562 Introduction to Robotics
Description: Introductory robotics including kinematics and inverse kinematics of robots, robot equations of motion, trajectory planning, actuators and sensors used in robots. Emphasis is placed on robots used in industry.

ECE 564 Fundamentals of Autonomous Robots
Description: Prerequisite: Senior standing, or permission of instructor. Co-requisite: ECE 565 Fundamentals of Autonomous Robots. Fundamentals of autonomous robots: sensors, path planning, machine perception, basic principles of AI, modeling, control and architecture. Case studies in industry and medicine will be discussed.

ECE 565 Autonomous Robots Laboratory
Description: Prerequisite: Senior Standing, or permission of instructor. Co-requisite: ECE 564 Fundamentals of Autonomous Robots. An autonomous robots laboratory experience in which the student becomes familiar with designing and building autonomous robots, using sensors, applying robotic paradigms and controller design. A final robotic competition will be held at the end of the semester.

ECE 614 Artificial Neural Systems
Description: Foundations of learning machines and neural processing algorithms: supervised and unsupervised learning of feed forward and recurrent neural networks, perceptron layers, associative memories, feature maps. Applications in the areas of classification, control, and signal processing. Implementation issues.

ECE 643 Introduction to Biomedical Computing
Description: Prerequisite: Graduate Standing. Note: Crosslisted with CECS 643. Covers various aspects of modern tools of biocomputing in its broad sense; hardware and software issues are covered. Topics include: Super and high performance computer architecture, high bandwidth networking, wireless computing, visualization, and software engineering in medicine. Topics also include computer-assisted interventions, imaging, parallel programming, and database design and query, as applied to life, medical and biomedical sciences.

ECE 661 Sampled-Data Control Systems
Description: Prerequisite: ECE 560. Analysis and synthesis of closed-loop sampled-data control systems using Z-transforms and state-space methods. Sampling and data reconstruction. Modified Z-transform. Time response and steady state accuracy. Stability analysis. Lag, lead, and PID controllers. Pole assignment. State estimation. Discrete optimal control

ECE 662 Introduction to Optimal Control
Description: Calculus of variations, dynamic programming, the minimum principle, and numerical optimization techniques applied to discrete-time and continuous-time deterministic control systems.

ECE 676 Foundation of Polymer MEMS
Description: An overview of the range of physical properties and applications of polymers, independent student readings and class reports on applications of polymers to the fabrication and operation of MEMS devices.

ENTR 600 Business Plan Development
Description: Prerequisite Enrolled Graduate status. The primary aim of this Graduate level course is to build all aspects of a business plan. The course specifically focuses on business model development, strategic positioning, funding sources as well as working entrepreneurially within an organization (profit or non profit). Restricted to Graduate level students from any discipline within U of L.

IE 563 Experimental Design in Engineering
Description: Prerequisite: Probability and Statistics for Engineers (IE 360). Note: Crosslisted with CECS 563. Design of engineering experiments and projects using theory of least squares, analysis of variance and covariance, randomized blocks, Latin squares, factorial experiments and associated topics. Engineering design problems using SAS and equivalent software packages.

IE 681 Human Performance
Description: The effect of physical environment on human sensory, motor, and information processes. Topics include heat, noise, light, vibration, sleep loss, illness, work load, work durations, and work-rest scheduling.

IMBA 652 Business Plan Competition I
Description: Teams are mentored by faculty coaches as they refine their business plan for presentation at a competition against other MBA teams.

IMBA 654 Business Plan Competition II
Description: Teams are mentored by faculty coaches as they refine their business plan for presentation at a competition against other MBA teams.

IMBA 664 Business Plan Competition III
Description: Teams are mentored by faculty coaches as they refine their business plan and compete in regional, national and international business plan competitions.

MBIO 601 Molecular Microbiology
Description: The course is an introduction to microbiology, focusing on the molecular make-up, function, and diversity of microorganisms, primarily bacteria. The pathogenic potential of bacteria will also be explored. Fall semester only. Graded.

MBIO 602 Immunology
Description: Prerequisite: Permission of course directors. This course provides an advanced introduction to innate and adaptive immunity at cellular and molecular levels including: identification of the cells of the immune system and their roles in various immune responses, the role and mechanisms of intercellular communication in induction and regulation of immune responses, gene rearrangement in formation of antigen receptors,regulation of antibody responses in response to infection, cytotoxic T cell responses against tumors and infectious agents, hypersensitivity reactions and autoimmunity.

MBIO 610 Methods of Analysis in Biomedical Sciences
Description: Note: Crosslisted with ASNB 610, BIOC 610, PHTX 610, PHZB 610. The primary goal of the Methods and Analysis course is to provide first year graduate students with the conceptual framework to become familiar with key tools and techniques used in biomedical science research. We will examine the kind of information the methodology can provide, the strengths and weaknesses of the approach and how data obtained can be judged and used to address scientific problems.

MBIO 618 Cell Biology of Viruses
Description: Building basic virology concepts and understanding various classes of viruses and basic steps common to their survival in nature- the need to enter, replicate and exit. Understanding how viruses rely upon their interaction with host cellular proteins to survive and how viruses cause disease.

MBIO 658 Cellular and Molecular Immunology
Description: Cellular and molecular aspects of normal and pathological immune responses including: cells and tissues involved in immune responses, antibody gene rearrangement and expression, antibody structure and function, antigen processing and presentation, T cell receptors, cytokines and co-stimulatory molecules.

MBIO 670 Molecular Virology
Description: Deals with fundamental properties of RNA- and DNA-containing viruses of animals and humans including the following subjects: molecular structure and composition of viral particles, intracellular viral replication, viral oncogenesis, recombinant viral vectors, and molecular aspects of viral chemotherapy and immunology.

ME 638 Continuum Mechanics (Computational Methods: Fluid Flow and Heat Transfer?)
Description: Prerequisite: Graduate School or Professional School Standing. Solutions of the momentum and thermal boundary-layer equations; methods of solving boundary-value problems using digital computers. Finite-difference methods, finite-element methods, and other methods for solving equations of fluid flow and heat transfer. Turbulence models.

ME 640 Optimum Design Methods
Description: Methods and applications of engineering design optimization. Strategies for problem formulation. Transformation methods, search techniques, linearization methods and quadratic approximation methods. Solution evaluation.

ME 647 Advanced Design Methods
Description: Prerequisite: ME 442 and ME 497. Practical techniques for product definition, concept generation and selection, value analysis, parameter design, design for manufacture, life cycle design and product structuring.

ME 650 Biofluid Mechanics
Description: Prerequisite: ME 401. Application of the Navier-Stokes equation to flow in the human body and to other biological systems.

ME 651 Kinematics and Kinetics of Human Movement
Description: Prerequisite: ME 206. Development of analytical tools for evaluating three-dimensional kinematics and kinetics of human motion.

ME 652 Advanced Human Dynamics
Description: Development of techniques for synthesis and analysis of kinematic and kinetic models of human motion, in conjunction with acquisition of biomechanical data associated with functional human movement.

ME 566 Graduate Engineering Mathematics (Advanced Engineering Mathematics II)
Description: Prerequisite: ME 565 or equivalent. Analysis of engineering systems and phenomena yielding complex domain models and solutions. Power series, Taylor series, and Laurent series. Complex analysis and potential theory. Numerical analysis for complex domain systems. Introduction to optimization and linear programming.

ME 671 Advanced Fluid Dynamics
Description: Prerequisite: ME 401. A study of the Navier-Stokes equation, with application to laminar and turbulent-flow fields for various geometries. Computer applications.

OBIO 501 Biomedical Data Analysis
Description: This course is designed for graduate and professional students in health sciences who require a working knowledge of the experimental design and statistical methods most often utilized in the biomedical sciences. The focus is upon the initial evaluation of scientific literature, the formulation of research protocols, and the interpretation of data. Special attention is given to those areas of data interpretation most common in the health sciences. Fall.

OBIO 600 Concepts in Oral Immunology
Description: Prerequisite: Students should have previously taken a basic immunology course or consent of i9nstructor. This course provides an in depth analysis of immune system function within the oral cavity. The control periodontal pathogens, as well as the intiation and progrssion of periodonatal diseases, are addressed

OBIO 601 Intro to Oral Biology Research
Description: Prerequisite: Acceptance to the degree program or consent of course director. Introduction to modern research methodology in oral biology. Designed to acquaint the student with a broad spectrum of experimental techniques and concepts which will help prepare for successful design of a research project. Major emphasis is placed on research design, research methodology, critical evaluation of basic research literature, and scientific writing.

OBIO 604 Oral Microbiology
Description: Prerequisite: OBIO 601 or professional school courses in microbiology and biochemistry. An in-depth study of the microbiota and host defense mechanisms with an emphasis on the ecology, nutrition, and biochemistry of the indigenous bacteria.

OBIO 611 Craniofacial Osteology
Description: Prerequisite: OPGD 801 and OPGD 805 or equivalents. Explores the hard tissue interrelationships of the cranifacial complex. Includes the mechanical properties, origins and maturation of facial bones. Complements the cephalometric course; designed to link clinical applications to anatomic locations.

OBIO 612 Craniomaxillofacial Diagnostic Imaging
Description: 2 lecture, 2-4 lab. Prerequisites: One of the following: Admission to the Graduate School for studies in Oral Biology; a DMS/DDS degree or its foreign equivalent; a MD/DO degree or its foreign equivalent. Note: Cross-listed with ASNB 678. To teach principles of safety, quality assurance, selection criteria and interpretation for current diagnostic imaging modalities of interest to the health care provider treating the craniomaxillofacial complex.

OBIO 617 Advanced Oral Pathology
Description: Prerequisite: One of the following: Admission to the M.S. Oral Biology program; a DDS, DMD, or MD degree or its foreign equivalent; consent of the instructor. Introduction to the clinical and radiographic manifestations of diseases of the oral cavity and para-oral region. Also included will be the clinical differential diagnosis oral lesions and the etiology and histology of common oral lesions. Clinical evaluation and management of oral lesions will be discussed as well.

PHTX 655 Neuropharmacology
Description: Prerequisite: PHTX 660 Principles of Drug Action or permission of instructor. This course will cover the mechanisms, effects and clinical applications of drugs that act on the autonomic, somatic and central nervous systems.

PHTX 656 Cardiovascular & Renal Pharmacology
Description: Prerequisite: Post baccalaureate or graduate status and successful completion of BIOC 645 or equivalent or permission of instructor. The goal is for students to gain an understanding of cardiovascular and

renal physiology, and properties of drugs affecting the heart, blood vessels and kidneys, blood cell formation, and coagulation.

PHTX 657 Endocrine and Metabolic Pharmacology
Description: Prerequisite: Post baccalaureate or graduate status and successful completion of BIOC 645 or equivalent. This course is a survey course of biomedical research and pharmacotherapeutic agents for management of a variety of endocrine and metabolic disorders.

PHTX 660 Principles of Drug and Chemical Action
Description: Prerequisites: organic chemistry and biochemistry. General principles governing the absorption, distribution, metabolism, excretion and mechanisms of drug action (drug pharmacokinetics and pharmacodynamics).