Special Issue on Research in Biomedical Engineering at the University of Illinois at Chicago: Fifty Years of Excellence

Bioengineering at UIC: Its Mission and Some Background.

The mission of the Richard and Loan Hill Department of Bioengineering is to provide an environment where students can achieve a high level of competence in the skills and knowledge inherent to the discipline of biomedical engineering/bioengineering (synonymous terms for accreditation). The discipline of bioengineering is distinguished by the application of quantitative engineering analysis and design to systems that include living components. Mastery of these skills and knowledge will prepare students for careers in the growing biomedical industry and for admission to graduate and professional schools.

Located in the heart of Chicago, the University of Illinois at Chicago (UIC) hosts a diverse constituency of students, attracted by the quality of UIC programs and the metropolitan setting. Recently, UIC was ranked third in the nation and eleventh in the world for institutions under fifty years of age. Since 2011 the Department of Bioengineering is in both the College of Engineering (COE) and the College of Medicine (COM) at UIC, home of one of the largest medical schools in the country. This arrangement is in line with best practices at other top programs around the country.

The Richard and Loan Hill Department of Bioengineering at UIC employs a rigorous and energetic process of continuous improvement of its curricula. Historically, graduates of our undergraduate program enter positions in industry (large firms and biotech startups), professional schools (medicine, dentistry, nursing, pharmacy, law), and graduate research programs. Alumni of our graduate M.S. and Ph.D. programs in bioengineering and bioinformatics have pursued careers in industry, academia, national research labs, and medicine.

Current enrollment totals over 100 Doctoral (Ph.D), 70 Master of Science (M.S.), and 270 undergraduate (Bachelor of Science, B.S.) students. There are currently about 30 core faculty members and over 100 adjunct faculty members with primary homes in many departments throughout the UIC Colleges of Liberal Arts & Science, Applied Health Sciences, Dentistry, Engineering, Medicine, and Pharmacy, or with homes in neighboring academic medical centers, such as Rush Medical University

Seven Things to Know about Bioengineering (BioE) at UIC.

1. According to *ForbesWoman*, May 15, 2012: "At No. 1, Biomedical engineering is the major that is most worth your tuition, time and effort. Biomedical engineers (bioengineers) earn a median starting salary of $53,800, which grows an average of 82% to $97,800 by mid-career. Moreover, the Bureau of Labor Statistics projects a 61.7 % growth of job opportunities in the field (from 2010-2020) – the most of any other major on the list."
2. UIC has one of the first degree-granting bioengineering programs in the nation. The program began in 1965 and received one of the first ten NIH Graduate Student Training Grants in Bioengineering (1966). UIC was the third program in the country that received ABET accreditation for its undergraduate degree (1976). The department received continued six-year accreditation renewal in 2014.
3. First department at UIC to be based in two colleges. Following other leading biomedical engineering (BME)/BioE departments in the country, such as at Johns Hopkins and Stanford, since August 2011, UIC Bioengineering has been a full member of both the College of Engineering

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and the College of Medicine.

4. In the same College as one of the largest medical schools in the country and in the same metropolitan region as five major academic medical research centers. Chicago is home to the academic medical centers of UIC, Loyola, Northwestern, Rush, and the University of Chicago, enabling many opportunities for training and research collaborations.
5. "Best of the Best" undergraduate students at UIC. Undergraduate students enrolled in engineering have the highest average ACT scores of any college at UIC and at any time in UIC's history. Students enrolled in BioE consistently have among the highest average ACT scores of any program in engineering at UIC.
6. Most gender-balanced engineering field. The field of bioengineering continues to attract a larger percentage of women than most other engineering fields at both undergraduate and graduate levels, approaching 50%.
7. Diversity is a strength and a source of pride for UIC and for BioE. Based on data from the US Department of Education, UIC ranks first in the percentage enrollment of underrepresented minorities when compared with the top 19 members of the Association of American Universities in this category. UIC is the only University in this top 20 list that is located in the Midwest and has a Latino/Hispanic population exceeding 25%. UIC is officially designated as both a Hispanic-Serving Institution and as an Asian American and Native American Pacific Islander-Serving Institution.

Faculty and students of UICC/UIC Bioengineering, past and present, gather for a group photo. Seated, left to right: Miiri Kotche, PhD (Clinical Associate Professor of Bioengineering), Robert Kenyon, PhD (Professor of Computer Science and Bioengineering), John W. Ahlen, PhD (first BS student of UICC/UIC Bioengineering), Richard L. Magin, PhD (University Distinguished Professor and former Head of Bioengineering), Bert L. Zuber, PhD (Professor Emeritus of Bioengineering), Earl Gose, PhD (Professor Emeritus of Bioengineering), Brenda Russell, PhD (Professor Emerita of Bioengineering and Physiology & Biophysics). Standing, middle row, left to right: James Lee, PhD (Associate Professor of Bioengineering), John Hetling, PhD (Associate Professor of Bioengineering), Jie Liang, PhD (Richard and Loan Hill Professor of Bioengineering), Terry Layton, PhD (Senior Lecturer of Bioengineering), William Pietrzak, PhD (BS 1977 and PhD 1988 degrees from UICC/UIC Bioengineering, member of External Advisory Board), Thomas J. Royston, PhD (Professor and Head of Bioengineering), Xincheng Yao, PhD (Professor of Bioengineering), G. Ali Mansoori, PhD (Professor of Bioengineering and Chemical Engineering). Standing, back row, left to right: Hananeh Esmailbeigi, PhD (Clinical Assistant Professor of Bioengineering), Salman Khetani, PhD (Associate Professor of Bioengineering), Robert Eisenberg, PhD (Chair Emeritus and Professor of Molecular Biophysics & Physiology at Rush, Professor of Bioengineering), James L. Patton, PhD (Professor of Bioengineering), Christos Takoudis, PhD (Professor of Bioengineering and Chemical Engineering), Tolou Shokuhfar, PhD (Associate Professor of Bioengineering), Richard Penn, MD (Affiliate Professor of Bioengineering), Irv Miller, PhD (Professor Emeritus of Bioengineering).

Celebrating Fifty Years

On November 20, 2015, a symposium was held in Chicago to commemorate the fiftieth anniversary of the founding of the undergraduate and graduate programs in Bioengineering at the University of Illinois at Chicago. Students, faculty, and alumni were invited to pay tribute to the founding faculty (Lawrence Stark, Earl Gose, Derek Hendry, Arne Troelstra, and Bert Zuber) for their dedication and vision in establishing a new department (http://bioe.uic.edu/BIOE/BioeFifty). The attendees also listened to talks by distinguished bioengineers (John Hetling, James Patton, Terry Layton, Robert Eisenberg, Robert Kenyon, and William Pietrzak) whose work is built upon the interdisciplinary foundations laid down fifty years ago. And to make the connections between past and present explicit the symposium was closed with a keynote address by distinguished alumnus Dr. John W. Ahlen, which was followed by comments from Founding Faculty Member and Professor Emeritus, Bert Zuber.

In this Special Issue of the journal *Critical Reviews of Biomedical Engineering* we are pleased to present five scholarly review articles describing some of the key areas of research under investigation by the faculty and students in the Department of Bioengineering at the University of Illinois at Chicago. Here we provide descriptions highlighting the contents and significance of each review article.

The coordination of sensory information systems in walking is an important topic of study in sensory physiology, rehabilitation medicine, and human factors research. In a paper,[1] "Sensory recalibration from visually amplified rotations while walking" by Tyler and coworkers, the authors describe how the relative role of the different senses can be manipulated in a full, three-dimensional virtual environment. They studied human subjects following a virtual path in the cave automatic virtual environment (CAVE) located in the electronic visualization laboratory (EVL) at UIC (https://www.evl.uic.edu/cave). The use of virtual environments expands the variety of sensory distortions possible beyond the more traditional prism and mirror eyewear. The study presented at http: //www.evl.uic.edu/pape/CAVE provides preliminary evidence that training periods of as short as 5 minutes in a distorted reality environment can recalibrate proprioceptive and vestibular senses due to the alteration of visual input. Such "adaptive training" provides the researcher and therapist with a more complex and subtle means to constructively enhance motor training and rehabilitation.

Atomic layer deposition (ALD) is an increasingly important technique in nanotechnology for processing surface features on biomaterials. In their paper,[2] "Atomic layer deposition in bio-nanotechnology: a brief overview," Bishal and coworkers describe how ALD can be used to synthesize thin films and to modify surface chemistry and functionalization. There are three general, different types of ALD: (i) thermal ALD, (ii) plasma enhanced ALD (PE-ALD), and (iii) radical enhanced ALD (RE-ALD). ALD is particularly promising because of its ability to tune the hydrophilicity/hydrophobicity characteristics of biomedical surfaces, to create conformal ultrathin coatings with the high aspect ratio needed for biomedical substrates, to alter the antibacterial properties of substrate surfaces, and to fabricate multifunctional biomaterials for medical implants. ALD can also be used to alter the mechanical, electrical, chemical, and other properties of materials that are increasingly used in biomedical engineering and biological sciences. Therefore, ALD is finding a wide range of applications from semiconductor processing to engineering nanometer and ångström surface features on biomaterials.

Molecular biosensors are necessary for the detection and monitoring of cellular processes. In their paper,[3] "Biomedical applications of quantum dots, nucleic-acid-based aptamers, and nanostructures for biosensors," Meshik and colleagues review the different classes of biosensors and detection techniques used for the quantification of analytes in biomedical applications. The review describes advances in molecular beacons incorporating semiconductor quantum dots, and nanoscale quenching elements; aptamer (short man-made oligonucleotides that bind to specific targets) based nanosensors on a variety of platforms, including graphene; Raman scattering and surface enhanced Raman scattering (SERS) from nanostructures and aptamers; and the electrical and optical properties of the nanostructures incorporated in these molecular beacons. The paper builds on work previously reported by this UIC team of investigators. These studies (using aptamer-based nanosensors, Raman and surface-enhanced Raman scattering, and direct physical property analysis of quantum dots), have established the use of molecular beacons as nanobiosensors in biomedical applications.

Light microscopy is an indispensable tool for examining the subcellular details of biological structures, but its spatial resolution is limited to approximately half the wavelength of the illumination light. In their paper,[4] "Super-resolution scanning laser microscopy based on virtually structured detection," Zhi and coauthors describe a new technique that can be safely used in clinical ophthalmoscopy to examine retinal structures.

Spatial resolution of conventional optical instruments is diffraction limited. In principle, optical resolution can be improved by increasing the numerical aperture (NA)—the range of angles over which the system can accept or emit light. However, the available NA cannot be adjusted for *in vivo* retinal imaging. In order to improve the resolution of retinal imaging, Professor Yao's group at UIC has recently demonstrated super-resolution scanning laser microscopy (SLM) based on virtually structured detection (VSD). This easy, low-cost, and phase-artifact-free strategy to achieve super-resolution has the potential to be used for *in vivo* super-resolution ophthalmoscopy. In this review, the authors provide a summary of rationale and limitations of currently available super-resolution approaches, explain the basic principle of the VSD-based scanning super-resolution microscopy, and discuss technical challenges and the potential of using the VSD-based method for *in vivo* super-resolution ophthalmoscopy.

Multiscale modeling of biological systems typically spans several orders of magnitude. In their paper,[5] "Multiscale modeling of cellular epigenetic states: stochasticity in molecular networks, chromatin folding in cell nuclei, and tissue pattern formation of cells," Liang and colleagues extend this range down to fundamental elements of DNA and up to the morphology of cells in tissue. Genome sequences we know provide the overall genetic blueprint of cells, while cells express the genome to exhibit diverse phenotypes. There are a multitude of mechanisms controlling cellular epigenetic states that dictate the behavior of cells. Among these, networks of interacting molecules, often under stochastic control, depending on the specific wirings of molecular components and the physiological condition, can have a different landscape of cellular states. In addition, chromosome folding in three-dimensional space provides another important control mechanism for selective activation and repression of gene expression. Fully differentiated cells with different properties grow, divide, and interact through mechanical forces and communicate through signal transduction, resulting in formation of complex tissue patterns. The development of quantitative models to study these multiscale phenomena and the identification of opportunities for improving human health requires new theoretical models, algorithms, and computational tools.

The articles included in this Special Issue describe only a small part of the research conducted by the students and faculty of the Department of Bioengineering at UIC, but we believe that they do provide the reader with a sense of the wide range of available expertise. This expertise has developed over the past fifty years in an environment of innovation and exploration that continues to operate today. We look forward to another fifty years of progress. Finally, we sincerely thank the journal editor, Markad V. Kamath, Ph.D., P. Eng., Begell House Vice President, Vicky Lipowski, and the rest of the staff of *Critical Reviews™ in Biomedical Engineering* for the opportunity to present to the bioengineering community a sense of the history and traditions of bioengineering at UIC and some of the current research that projects toward its promising future.

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