IEM ANNUAL REPORT
2015-2016

Institute for Engineering in Medicine
University of Minnesota
Driven to Discover™

www.iem.umn.edu
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**Director’s Message**

“The future of medicine and healthcare requires collaborative efforts that address grand challenges through innovating engineering solutions that effectively diagnose, treat, and prevent diseases. That is why the Institute for Engineering in Medicine plays a significant role promoting interdisciplinary collaborations between engineers and biomedical scientists.”

IEM is an interdisciplinary research organization that advances engineering solutions to medical and health problems by fostering collaborations between engineering and biomedical faculty at the University of Minnesota and between University faculty and industrial colleagues. Challenges to today’s and tomorrow’s medicine and healthcare necessitate interdisciplinary and multidisciplinary collaborations. The membership of IEM consists of more than 240 University faculty representing more than 50 academic departments. These members are tackling challenges in Cardiovascular Engineering, Neuroengineering, Cellular and Molecular Bioengineering, Medical and Biological Imaging, and Medical Devices.

The past year has been pivotal for the Institute for Engineering in Medicine (IEM). The Institute has expanded its reach, its impact, and the University of Minnesota’s connection to industry. IEM organized multidisciplinary faculty groups through the seed group grants, many of which led to research collaborations and major federal grants. IEM organized individual investigators from biomedical and engineering disciplines in order to explore collaborative research. These modest investments have resulted in significant external funding, representing a significant return on investment. IEM has also organized or sponsored well-attended conferences and symposia including the popular Design of Medical Devices Conference and the Minnesota Neuromodulation Symposium, both of which attract a significant number of participants from academia, industry, and government. In addition, the IEM Annual Conference and Retreat has become a highly-interactive platform to facilitate collaborations between engineers, biomedical scientists, and clinicians.

Two significant new IEM initiatives in 2015-16 were the establishment of the IEM Industrial Fellows and IEM Clinical Immersion Program. The industrial Fellows help connect industry with the University of Minnesota by communicating their needs and assisting with the establishment of collaborative activities. The Clinical Immersion Program provides a uniquely valuable experience for engineers and other professionals from medical technology companies by having them spend a full week with either surgeons or interventional cardiologists.

In this annual report, you will find information about the theme programs and affiliated research centers of IEM, highlights of recently recruited IEM members’ research, and IEM education and outreach activities. We look forward to your continued interest and support. Please contact me at iem@umn.edu with ideas that can improve what we do. Together, we will make a difference in tomorrow’s medicine and healthcare through engineering innovation.

Sincerely,

Bin He
Director, Institute for Engineering in Medicine
Institute for Engineering in Medicine

ABOUT IEM
The University of Minnesota’s Institute for Engineering in Medicine is an inter-disciplinary research organization seeking engineering solutions to tomorrow’s medicine and health care needs while strengthening research cooperation between the Academic Health Center and College of Science & Engineering as well as fostering collaborations with the medical device industry.

ORGANIZATION
IEM hosts six research centers and organizes its members’ research into five themes. Most IEM members are from departments in the University’s Academic Health Center or College of Science and Engineering. As an organization dedicated to building partnerships with a wide variety of medical, clinical, and engineering professionals, IEM highly values the involvement of scientific and industrial advisors from outside the University.
MISSION

The Institute for Engineering in Medicine (IEM) at the University of Minnesota serves as a catalyst for facilitating multidisciplinary collaborations in research and education between the Academic Health Center and the College of Science and Engineering, in addition to fostering collaborations with the medical technology industry. IEM seeks to be the world leader in applying engineering solutions for improving human health and well-being. This is truly where medicine meets technology creating tomorrow’s innovations.

VISION

As health care costs continue to rise exponentially and the world’s population ages, innovative and transformative approaches are needed now more than ever to deliver high-quality, safe and cost-effective care. IEM will champion the application of engineering technologies to generate innovative approaches for better treatment and management of a wide range of disorders. IEM members will develop programs that combine scientific advances with medical knowledge to improve the diagnosis, treatment, and prevention of diseases that affect our society.

IEM integrates expertise in engineering technology, basic sciences, biological and medical sciences, and the social aspects of health care. The position of IEM within the University—along with the University’s strong relationship with the Minnesota state government, support of the public, and presence amidst the heart of the world’s medical device industry—provides a unique environment for integrating new technologies into clinical practice and patient care. IEM is positioned to advance multi-disciplinary engineering solutions for all segments of health care, and will foster innovations from basic science through discovery with impact for patient care, technological translations, and societal impact.
Institute for Engineering in Medicine

EXECUTIVE COMMITTEE

IEM’s Executive Committee is composed of eminent University of Minnesota faculty from the biomedical sciences and engineering disciplines. Their passion for innovation and growth puts them in a unique position to promote the mission of IEM while actively contributing to research, education, clinical and industry needs, and technology transfer. Under the guidance of Director Bin He, Executive Committee members attend operational meetings, chair IEM research themes, direct IEM centers, and promote interdisciplinary efforts to address challenges in engineering in medicine.

BIN HE, PH.D.
IEM Director; Distinguished McKnight University Professor of Biomedical Engineering; Medtronic-Bakken Endowed Chair for Engineering in Medicine

“The future of medicine and healthcare requires collaborative efforts that address grand challenges in employing innovative engineering solutions to effectively diagnose, treat, and prevent diseases. The Institute for Engineering in Medicine plays a significant role to promote collaborations between engineers and biomedical scientists. I enjoy the opportunity to collaborate with colleagues from other disciplines and to help enhance such opportunities for others.”

JOHN C. BISCHOF, PH.D.
IEM Associate Director for Development; Distinguished McKnight University Professor of Mechanical and Biomedical Engineering and Urology; Carl and Janet Kuhrmeyer Chair in Mechanical Engineering

“The Institute for Engineering in Medicine is a unique structure that brings together basic, translational, and clinical biomedical engineers and scientists at the University of Minnesota. I have benefited intellectually from the diverse and rich group of collaborators within IEM membership. IEM helps increase the societal impact of existing and helps to build new biomedical research groups at the University of Minnesota.”

PAUL A. IAIZZO, PH.D.
IEM Associate Director for Education and Outreach; Director of the Visible Heart® Laboratory; Professor of Surgery, Integrative Biology, Physiology, and the Carlson School of Management; Medtronic Professor of Visible Heart® Research, Distinguished University Teaching Professor

“The Institute for Engineering in Medicine continues to promote device development through interfacing clinicians, basic scientists, engineers, and industry which serves to carry on the rich tradition of innovative collaborations at the University of Minnesota such as the one between C. Walton Lillehei and Earl Bakken.”

VICTOR BAROCAS, PH.D.
Professor and Director of Graduate Studies for Biomedical Engineering; College of Science & Engineering Distinguished Professor

“More and more, we see new ideas and technologies arise from collaboration between clinicians and engineers. I am excited to join the IEM team and help promote greater interactions among researchers, especially in the cardiovascular arena.”

WEI CHEN, PH.D.
Professor of Radiology

“The Institute for Engineering in Medicine enhances research opportunities and broadens collaborations with other researchers with different backgrounds.”

STEPHEN ENGEL, PH.D.
Professor of Psychology

“It is now clear that major breakthroughs in treatment and research result from interactions between clinicians, engineering, and basic scientists. The Institute for Engineering in Medicine plays a critical role in forming and fostering these interactions, steering research toward translational applications and clinicians towards relevant research.”
KELVIN O. LIM, M.D.
Drs. T.J. and Ella M. Arneson Land-Grant Chair in Human Behavior; Professor and Vice Chair of Research, Department of Psychiatry

“Psychiatry is in need of new approaches for clinical assessment and interventions. The Institute for Engineering in Medicine provides a home base for the Medical Devices Center and a connection to the Academic Health Center, particularly its Medical School. IEM’s Executive Committee consists of colleagues who strive to enrich the University’s contribution to improvement in healthcare.”

DAVID ODDE, PH.D.
Professor of Biomedical Engineering

“We need to connect genomic and molecular level information to the physical workings of cells in their environment. The Institute for Engineering in Medicine provides the engineering perspective on the cell and connects it to medically relevant problems.”

JIAN-PING WANG, PH.D.
Distinguished McKnight University Professor of Electrical and Computer Engineering

“The Institute for Engineering in Medicine provides an extremely important cross-disciplinary platform for interaction with other researchers from the Academic Health Center and medical device industry, especially to fully understand the needs and criteria for early disease detection and drug discovery.”
SHU CHIEN, PH.D.
Director of UCSD Institute of Engineering in Medicine
University Professor of Bioengineering and Medicine at UCSD
Member, National Academy of Engineering
Member, National Academy of Sciences
Member, National Academy of Medicine

Shu Chien is a world leader in molecular, cellular and integrative studies on bioengineering and physiology in health and disease. His current research interests are mechanotransduction in endothelial cells in health and disease and the role of microenvironments in modulating stem cell fate.

ARTHUR F. KRAMER, PH.D.
Swankund Chair and Professor of Psychology and Neuroscience at the University of Illinois at Urbana-Champaign
Director of the Beckman Institute for Advanced Science and Technology

Professor Kramer’s research projects include topics in cognitive psychology, cognitive neuroscience, aging, and human factors. A major focus of his lab’s recent research is the understanding and enhancement of cognitive and neural plasticity across the lifespan.

RAPHAEL LEE, M.D., SC.D.
Paul and Allene Russell Professor of Surgery (Plastic)
Professor of Medicine (Dermatology) and Organismal Biology and Anatomy at the University of Chicago
Member, National Academy of Engineering

Raphael Lee focuses much of his research on the effects of physical forces on tissue injury and healing processes, pharmaceutical control of scar formation, and reconstructive surgery. He is also a founder and Chairman of the Board of Directors for Avocet Polymer Technologies, Inc., Renacyte BioMolecular Technologies, Inc., Electrokinetic Signal Research, and Maroon Biotech, Inc., all of Chicago, Illinois.

ALVARO PASCUAL-LEONE, M.D., PH.D.
Professor of Neurology and Associate Dean for Clinical and Translational Research at Harvard Medical School
Chief for the Division of Cognitive Neurology
Director of the Berenson-Allen Center for Noninvasive Brain Stimulation at Beth Israel Deaconess Medical Center

Dr. Pascual-Leone is a world leader in the field of noninvasive brain stimulation, where his contributions span from technology development, through basic neurobiologic insights from animal studies and modeling approaches, to human proof-of-principle and multicenter clinical trials.

P. HUNTER PECKHAM, PH.D.
Donnell Institute Professor at Case Western Reserve University
Director, Functional Electrical Stimulation Center
Member, National Academy of Engineering

P. Hunter Peckham is a leading expert in functional electrical stimulation, which is most commonly used to restore control of paralyzed extremities. His research includes work with sensors, stimulators, electrodes, and neuroprostheses that enable cervical spine injury patients to regain functionality of hands and arms.
INDUSTRIAL ADVISORY BOARD

TONY CLINCH
V.P., Research & Development, 3M Health Care Business Group

Mr. Clinch leads Research and Development for 3M Health Care and serves as a Strategic Advisory Board member for MnDRIVE (Minnesota’s Discovery, Global Food, Environment and Brain Conditions).

DOUGLAS DAUM, PH.D.
V.P., Research & Development, Electrophysiology, Boston Scientific

Dr. Daum holds more than 50 patents and is the author of more than a dozen peer reviewed publications in engineering and medical journals.

PHIL EBELING
Senior V.P., Research & Development Cardiovascular & Electrophysiology Franchises, St. Jude Medical

Mr. Ebeling has been with St. Jude Medical for 7 years and serves on several academic and other non-profit boards of directors both locally and nationally.

TIM LASKE, PH.D.
V.P., Research and Business Development, Medtronic AF Solutions

Dr. Laske is a founding member of the BioBusiness Alliance of Minnesota and has over 60 patents and numerous publications in the field of Biomedical Engineering and Wildlife Biology/Ecology.

SHAYE MANDLE, J.D.
President & Chief Executive Officer, Medical Alley Association

Mr. Mandle has nearly 20 years of leadership experience in government, the private sector, and academia. He has managed state and federal election campaigns and led two industry and economic development organizations.

BILL MURRAY
President and CEO, Medical Device Innovation Consortium

Mr. Murray has over 25 years of senior leadership experience spanning the range of privately financed start-ups to multi-billion dollar global businesses.

RANDY SCHIESTL
V.P., Research & Development, Global Technology, Boston Scientific

Mr. Schiestl leads a team of talented R&D engineers, scientists and technicians chartered to develop and sustain a broad family of minimally invasive medical devices.
RESEARCH THEMES

Research at IEM is focused around five core themes: Cardiovascular Engineering, Neuroengineering, Cellular and Molecular Bioengineering, Medical and Biological Imaging, and Medical Devices. These represent IEM’s dedication to creating interdisciplinary research teams that aim to understand the mechanisms of disease and develop engineering solutions to diagnose, treat, and prevent a wide variety of health problems.

True to the interdisciplinary nature of IEM, many IEM-sponsored research projects combine one or more of these themes, and many IEM members regularly conduct cross-theme research.

CARDIOVASCULAR ENGINEERING
Co-Theme Chairs: Victor Barocas, Ph.D. and Paul Iaizzo, Ph.D.

The major goal of the Cardiovascular Engineering Theme is to address the global public health challenge of cardiovascular diseases by studying the heart at the gene, cell, tissue, and whole-organ levels. Research teams also develop novel imaging and sensing modalities to study the mechanisms of cardiovascular functions and guide engineering solutions for clinical diagnosis and management.

NEUROENGINEERING
Theme Co-Chairs: Bin He, Ph.D. and Kelvin Lim, M.D.

The goal of the Neuroengineering Theme is to develop multi-level solutions that involve the operation of whole neural systems. IEM researchers in this theme focus on developing methods to detect, image, interface with, and modulate brain and nervous system disorders. They also focus on developing non-invasive methods for understanding and healing the brain.


Image: Illustration of a novel noninvasive brain-computer interface that can control the flight of a virtual helicopter in 3-D virtual space at the University of Minnesota campus from “thoughts” sensed over the scalp of human subjects. Work published in PloS ONE (Doud et al) and featured by ABC News.
CELLULAR AND MOLECULAR BIOENGINEERING
Theme Co-Chairs: Kalpna Gupta, Ph.D. and David Odde, Ph.D.
The Cellular and Molecular Bioengineering Theme has the research goal of developing therapeutic strategies at the cellular level to halt disease and promote regenerative healing. Building upon genome sequencing projects, theme researchers apply modeling and advanced instrumentation to understand how molecular parts form functioning systems that enable cells to execute specific disease-related tasks and use these models to design novel therapeutic strategies.

MEDICAL AND BIOLOGICAL IMAGING
Theme Co-Chairs: Wei Chen, Ph.D. and Stephen Engel, Ph.D.
The major research goal of the Medical and Biological Imaging Theme is to strengthen the role of imaging in support of biomedical research and clinical translation. Researchers pursue this goal by integrating and sharing a large variety of state-of-the-art imaging approaches and fostering interdisciplinary collaborations among basic science, bioengineering, and clinical researchers in academia and the biomedical industry. Researchers in this theme also develop grant proposals to procure state and federal funding for interdisciplinary imaging research. Imaging technologies available include MRI, in vivo MRS, PET, CT, ultrasound, optical imaging, and cellular and electrophysiological imaging.

MEDICAL DEVICES
Theme Co-Chairs: Arthur Erdman, Ph.D., Christy Haynes, Ph.D., and Jianping Wang, Ph.D.
The goal of the Medical Devices Theme is to develop devices and technologies that aid in the diagnosis, treatment, and management of various diseases. Emphasis is placed on engineering innovations that address unmet medical needs. For more information on this research theme, see the description of the Medical Device Center on page 22.
Despite significant advances in the last three decades, Magnetic Resonance Imaging (MRI) still demands trade-offs between time and resolution. Short scan times result in poor spatial and temporal resolutions, hindering MRI from its full diagnostic and prognostic utility.

Professor Mehmet Akçakaya aims to reduce MRI scan times by sub-sampling MR data and exploiting inherent redundancies in images and contrast mechanisms. Right now, for example, a high-resolution MRI of coronary arteries takes 10-12 minutes. Prof. Akçakaya aims to cut that to 3-4 minutes with his “LOST” method (for Low-dimensional-structure Self-learning and Thresholding), making it easier to perform scans on people who have difficulty remaining motionless and freeing up much-needed time on MRI scanners.

Prof. Akçakaya, who was an instructor at Harvard Medical School before joining the University’s Department of Electrical and Computer Engineering, exploits patient- and anatomy-specific self-similarity within an image to “learn” anatomical structures from the sub-sampled data, itself. This technique has reduced both blurring and noise in a number of applications – including coronary artery and myocardial viability imaging – and is currently used clinically. Prof. Akçakaya continues to combine these learning techniques with other redundancies in MRI acquisition protocols and hardware.
If robots can perform minute, extremely precise movements repeatably, can they be used to study brains in vivo? Suhasa Kodandamaiah, the University’s new Benjamin Mayhugh Assistant Professor in Mechanical Engineering, certainly thinks so. In fact, he thinks that robotic tools will significantly expand the amount and types of research that neuroscientists can carry out.

One of Kodandamaiah’s research projects, for example, involved building an “autopatcher” that guides microscopic recording needles to measure the activity of neural cells by establishing direct contact with their cell membranes. Normally, such “patching” is an arduous task, requiring months of training and days of set-up. Kodandamaiah’s automated system, used on anesthetized and awake mice by a non-specialist, was able to record neuronal activity with speeds and resolutions that matched or beat those of experienced human investigators.

Just as importantly, the autopatcher, which comes with interpretive algorithms, was also able to observe multiple neurons in circuits. This opens the door to easily measuring the parallel activity of hundreds or even thousands of cells from a particular brain region. Moreover, it will allow thousands of scientists without special training to study highly localized brain activity in vivo, which will pave the way to more systematic mapping of brain regions and activity.

After earning his PhD from the Georgia Institute of Technology in 2013, Prof. Kodandamaiah worked for two years as a post-doctoral researcher at MIT before coming to the University of Minnesota.

Image 1: Autopatcher schematic showing robotically guided single cell recording probes.

Image 2: Kodandamaiah’s autopatcher.
BRAIN NETWORKS AND OPTICAL INTERVENTION

Different types of neurons form networks in the brain that link up to form larger circuits. But how do these circuits and their varying neurons contribute to brain function? The Krook-Magnuson lab in the Department of Neuroscience tries to answer this question, with special emphasis on what goes wrong in neurological disorders and how neurons and circuits can be manipulated to improve outcomes.

As a postdoc in Dr. Ivan Soltesz’s lab at the University of California, Irvine, Dr. Krook-Magnuson and colleagues were the first to develop “on-demand optogenetics” for temporal lobe epilepsy, a technique to detect epileptic seizures early and to selectively manipulate neurons with light. With this technique, they were able to stop seizures in mice, often before the seizures became debilitating.

At the University of Minnesota, Dr. Krook-Magnuson continues to employ this and other techniques to identify new intervention strategies for epilepsy and to unravel mysteries of brain circuitry.
INTERFACING WITH BRAINS

As a graduate student and post-doctoral researcher at CalTech and the University of Cambridge, England, Andrew Lamperski studied the biological feedback control that allow animals to successfully navigate their worlds. As a new University of Minnesota professor, he’s applying his insights to robotic arms and deep-brain stimulation.

The first line of research, conducted in collaboration with IEM Director Bin He, involves developing estimation techniques to model relationships between electroencephalography (EEG) signals (or “brain waves”) and intended arm movements. The aim is to streamline brain control of robotic limbs.

Lamperski’s deep brain stimulation research, carried out with fellow IEM member Prof. Theoden Netoff, is geared toward creating adaptive therapies for seizure patients. Lamperski’s group is developing algorithms to model the effect of electrical stimulation on brain activity in order to test different stimulation effects as brain activity changes.

Image 1: IGERT student Tyler Lekang (with the EEG cap) and Andrew Lamperski working with a robotic arm.
Image 2: A comparison of predictions (blue and green lines) and actual measurements (pink) of a rat brain’s local field potential at discrete stimulation times (below).
ULTRASOUND BRAIN THERAPY

Ultrasound is well-established as a non-invasive imaging technique, helping diagnose pre-natal health, cardiac abnormalities, and many other medical concerns. Where others see a diagnostic tool, however, Dr. Wynn Legon sees a vehicle for the treatment of psychiatric and neurological disorders.

The great advantage of ultrasound for neural therapy is that it has very high spatial resolution and can be focused deeply to target specific neural structures. Dr. Legon’s work at the University, where he is a MnDRIVE scholar and Assistant Professor in the Program in Physical Therapy, aims to model and characterize ultrasound beam propagation through human tissue. Building on this work, he also hopes to develop custom ultrasound equipment and procedures for better ultrasound stimulation of humans. His lab was the first to document that transcranial focused ultrasound can be safely used in humans to induce changes in cortical excitability.

Legon is also studying ways to combine ultrasound and MRI for therapeutic purposes. His lab was the first to show that peripheral ultrasound stimulation and functional MRI could be successfully combined in humans.
3D PRINTING FOR LIFE

In just a decade, 3D printers have gone from odd novelties in academic labs to workhorses in industry, universities, and even homes. For Dr. Michael McAlpine, however, the 3D printing revolution is just getting started, especially when it comes to functional materials and devices.

McAlpine notes that most 3D printouts are hard plastic objects based on melting and cooling polymers – in other words, they are not easily adaptable to soft and low-temperature biological systems. His solution: build new printers from scratch that can print and even interweave biological and electronic materials. His goal is to develop materials and printers that can make medical devices, prosthetics, and human-machine interfaces that are individualized for each user.

McAlpine’s lab, which is sponsored by the Army, Air Force, DARPA, NSF, NIH, and industry giants DuPont and Lockheed Martin, takes a three-pronged approach to developing 3D printers for living systems:

• Use improved imaging and printing resolutions to produce customized, interwoven, anatomically-accurate devices
• Test and develop nanoparticle-based inks for expanding the scope of 3D printed materials
• Integrate 3D printed materials and devices with biological and biomedical platforms

McAlpine is the Benjamin Mayhugh Associate Professor of Mechanical Engineering. He came to Minnesota after receiving his Ph.D. from Harvard University and teaching for seven years at Princeton University.

Image 1: Programmable release capsules printed with engineered tissue within a hydrogel matrix.

Image 2: A printed nerve regeneration pathway implanted in a rat.

Image 3: A bionic ear printed from silver particles, a cell-laden hydrogel, and silicone.
BRAIN FOLDING AND BRAIN HEALTH

If a ligament or tendon is even slightly out of place, we feel discomfort. But what if part of a brain is out of place?

While studying at a university hospital in Marseille, France, Dr. Michael Park began analyzing the MRIs of epilepsy patient brains. He noticed that areas with abnormal “sulcogyral patterns” – that is, folding on the micro- and macro-level – were also areas highly prone to seizures.

Now an assistant professor of Neurosurgery at the University of Minnesota and a MnDRIVE scholar, Park focuses much of his research on developing better ways to perform sulcogyral analysis. By detecting abnormal folding, Park aims to more quickly identify brain areas associated with seizures, depression, schizophrenia, autism, and other disorders. This in turn will help him and other scientists and physicians address these areas with various types of neurotherapy.

Before coming to the University of Minnesota, Park was an assistant professor in the Department of Neurological Surgery at the University of Louisville School of Medicine in Kentucky.

“In movement disorders, we’re directly manipulating the brain’s circuitry with an electrical device to modify its function or modify the way the brain is working to improve the patient’s quality of life.”
- Michael Park
Neural stimulation has been used in the past decades to treat many neurological disorders and restore neural functions. In that time, implantable stimulation devices have become smaller and more efficient, but they are still too large to be minimally invasive. In addition, none of them can simultaneously stimulate and record the effects of stimulation.

Zhi Yang, an assistant professor of Biomedical Engineering and a MnDRIVE scholar, recently invented “Neuronix,” a system-on-chip neurotechnology that can simultaneously stimulate and record electrical impulses in neural tissue. He was the first to demonstrate the effectiveness of such a device in an animal model, and he has also demonstrated that the chip can be used with brain and peripheral nerve and similar systems will significantly improve neurotherapy and neuroscience research. For example, with instantaneous neural responses, clinicians will be able to make adjustments during stimulation therapy to improve safety and treatment outcomes. Researchers will also be able to perform a bidirectional neural communication or precise neuromodulation to better understand brain circuits and function.

Yang is currently collaborating with other University of Minnesota researchers and industry partners to move Neuronix toward commercialization.
Pressure wounds (or “bed sores”) have been called a “silent epidemic” that pose a significant threat to public health. They affect over 2.5 million patients and result in an estimated $11 billion in health care expenses each year in the U.S. alone. The key problem is that they are not easy to prevent. Conditions that cause tissue damage differ widely among patients, and the damage is often severe before a wound becomes visible.

With her colleagues at UC Berkeley and the UC San Francisco Medical Center, Prof. Swisher printed an array of dozens of electrodes onto a thin, flexible film. Then they placed the film directly on shaved rats with minor skin injuries. Knowing that damaged cells conduct electricity differently than healthy cells, the researchers were able to map skin health by simply discharging a very small current between each pair of neighboring electrodes. These results demonstrate the feasibility of an automated, non-invasive “smart bandage” for early detection of pressure ulcers.

For Swisher, a smart bandage is just one example of how flexible electronics built with nanomaterials can enable innovative technologies for disease diagnosis and treatment. Her group is currently developing flexible materials for neural interfaces, low-cost sensors for monitoring patients at home, wearable electronics, large-area sensors, and “smart” soft robotics.
At any given time, several IEM members are working to commercialize important research begun at the University of Minnesota. Here are three who have combined research, industry partnerships, venture capital, and resources at the University such as the Office of Technology Commercialization to move their insights to the marketplace:

**Carston R. Wagner**, Department of Medicinal Chemistry, School of Pharmacy. Company: Tychon.

“Teaching the body to fight cancer again” – that’s the premise of Tychon, a company founded in 2014 by Carston Wagner in conjunction with a venture incubator group. Based on IEM-funded research conducted by Wagner and many other University professors, Tychon’s technology is aimed at developing cancer-fighting immunotherapies by modifying a patient’s T-cells to kill tumors. The company is also developing nanorings that guide T-cells to tumor sites. Tychon has raised $3 million in pre-series A funding while conducting proof-of-concept studies and is seeking partnerships with both venture and pharma investors.

**Perry B. Hackett**, Department of Genetics, Cell Biology, and Development; College of Biological Sciences. Companies: Discovery Genomics and Recombinetics. The focus of Discovery Genomics since its founding in 2000 (by Hackett and three other University professors) has been identifying functions of genes that can act as targets for pharmaceuticals and developing gene therapies that do not require viruses as delivery vehicles for therapeutic genes. Research has been conducted on zebrafish, mice, and dogs as a vital step in drug development for several pharmaceutical companies. The company was recently acquired by Immusoft, a Seattle-based immunotherapy company. Recombinetics, founded in 2008 (by Hackett and two other University professors), is developing animals for improved agricultural efficiency and animal welfare as well as animals that will significantly reduce the time needed to test drugs and other therapies before human trials. The company is also developing animals that will host human tissues and organs for transplantation and currently collaborates with University professors and IEM members.

**Alptekin Aksan**, Department of Mechanical Engineering, College of Science and Engineering. Company: Minnepura. Back in 2010, Prof. Aksan and a fellow University professor thought that, instead of using standard filtering techniques to purify water, it would be better to stream water over silica-encased enzymes that break pollutants into harmless components. This idea is now the foundation for Minnepura, which is currently engaged in water purification around the country. The company, which is now in its third year, has recently partnered with a large agricultural company to remove the common herbicide atrazine from water supplies. It has also been contracted to conduct research aimed at removing common contaminants from commercial pools and spas, and it plans to use revenue and further investment to expand its product lines.
IEM Research Centers

MEDICAL DEVICES CENTER

The College of Science and Engineering established the Medical Devices Center (MDC) in 2008 to develop innovative devices through applied and translational research, education and training, outreach, and public engagement. More specifically, MDC equipment, expertise, and engagement help researchers overcome common barriers between great ideas and a prototype medical device:

- MDC's equipment includes a 3D virtual prototyping lab, dozens of general and specialized machine tools, and six 3D printers, all of which print directly from digital models and can print with two materials simultaneously.
- MDC's expertise includes access to experts at every stage: equipment training, basic prototyping guidance, legal and intellectual property guidance, and clinical trial planning.
- MDC's engagement stems from its active and productive culture. At almost any given time, someone is around for sharing ideas, getting feedback, and supporting the difficult concept-to-reality road for medical devices.

MDC's 2015-16 was busy and productive. New equipment and space helped meet increased demand for its services, which Director Arthur Erdman credits to the vibrant medical device community in the Twin Cities and an increased emphasis at the University to identify unmet clinical needs and direct research toward commercializable medical products.

In the coming year, Erdman aims to increase the number of industrial partnerships to include companies outside the Twin Cities and even outside the U.S. Building on the new initiative of Dr. Marge Hartfel (see highlights below), Erdman also foresees more well-organized teams of volunteers to help University physicians, nurses, and faculty move device ideas more quickly to prototypes, clinical testing, and potential commercialization. MDC's recent expansion into the Mayo Building has barely met demand, so finding more space is also on Erdman's agenda.

2015-2016 HIGHLIGHTS

- Coordinated four first-in-human trials for local medical device companies
- Added 550 square feet of meeting and 3D printing space in the Mayo Building
- Dr. Marge Hartfel, a retired product developer at 3M (and former graduate student of Arthur Erdman) began coordinating undergraduate and graduate volunteers to work on project-specific teams led by MDC mentors
- Over 1800 people toured the facility: approximately 900 from K-12 and academia, 500 from industry, 300 from government entities, and 100 from medical facilities
- 30 Senior Design Teams used the facilities to complete projects
CENTER FOR NEUROENGINEERING

IEM’s Center for Neuroengineering (CNE) fosters interdisciplinary collaborations between neuroscience, engineering, clinical faculty and industrial partners to address challenges in basic and clinical neuroscience. CNE also educates the next generation of leaders in this dynamic field by hosting a biweekly neuroengineering seminar series and regular training of undergraduate and graduate students, researchers, and industry professionals. The Center is also affiliated with the Institute for Translational Neuroscience. It is organized into three themes: neural decoding and imaging, neural sensing and interfacing, and neuromodulation. CNE has state-of-the-art laboratories distributed among multiple departments for sensing, imaging, stimulation and interfacing research, and is engaged in inter-institutional collaborations with Mayo Clinic, Rochester.

CNE faculty have made significant research advancement in 2015-2016, including computational imaging based brain-computer interface, computational modeling guided deep brain stimulation, transcranial ultrasound stimulation among others. CNE embarked on several educational outreach efforts in 2015-2016. The IGERT training program blossomed, reaching over 1900 K-12 students and faculty through dozens of presentations, demonstrations, tutoring sessions, and other venues for neurotechnology and STEM education. This program – which is one of only three IGERTs in the nation dedicated to neuroengineering – also drove a significant amount of hands-on training by sponsoring the research of 24 graduate students. In 2015-2016, the NIH T32 predoctoral training program in integrative neuroimaging started its renewed phase, and funded the research of two graduate students in the Biomedical Engineering and Physics departments.

CNE also began a new educational program for undergraduates in 2015-16. Funded through a new NSF Research Experience for Undergraduates (REU) grant, led by Professors Tay Netoff and Matt Johnson, the program guides eight students through 10 weeks of neuroscience training with seminars, participation in a research project, and mentorship from a professor and graduate student.

2015-2016 HIGHLIGHTS

- 8 new NIH R01 grants awarded to CNE faculty as PIs.
- Outreach to 1900 K-12 students by CNE faculty and graduate students.
- Trained 8 undergraduate students via NSF funded REU.
- Over 480 researchers from academia, industry, and government attended the Minnesota Neuromodulation Symposium in April (see p. 33).
- A January 2016 IEEE Transactions on Biomedical Engineering paper by CNE Director Bin He and graduate students Bradley Edelman and Bryan Baxter has been the journal’s most viewed and downloaded paper of the year.
The Biopreservation Core Resource (BioCoR) was established in 2010 through funding from IEM, the College of Science and Engineering, and the Academic Health Center. Under the direction of Prof. Allison Hubel of the Department of Mechanical Engineering, BioCoR’s mission is to advance the science, technology and practice of preservation. This means that BioCoR aims to improve the preservation of molecules, cells, and tissues by creating preservation protocols and standards, developing preservation and storage technologies, and training individuals and institutions in the science and technology of biopreservation.

According to Hubel, BioCoR meets two major challenges: 1) The state-of-the-art for biopreservation has not advanced much in the past 30 years, and many who use biopreservation systems do not understand the science behind them; and 2) The demand for cellular therapies is exploding throughout the world, but there simply is not enough biopreservation infrastructure to promote large-scale developing, testing, and expansion of new therapies.

Over the past year, BioCoR has invested in new ways to provide biopreservation resources and training (see sidebar). Hubel plans to continue these efforts in 2016-17 and hopes to expand BioCoR’s education outreach to more industrial partners.

Hubel also aims to expand BioCoR’s research partnerships with industry, especially for developing large-scale production and preservation of cells. Research directed to developing better liquid and cryo solutions for longer organ and tissue preservation is also high on Hubel’s priority list, along with cryo solutions for cells. Such developments would enable more people to receive life-saving transplants, and they would help scientists around the world form more research collaborations on promising cell lines.

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**2015-2016 HIGHLIGHTS**

- Launched a new website with improved navigation, new resources, and an expanded capability for updating information and resources.
- Competed successfully for a five-year NIH workforce training grant with Prof. Dave McKenna (Department of Laboratory Medicine and Pathology) and 17 other University faculty. This grant funds intensive 3-6 month, on-site training for graduate students, postdoctoral fellows, and early career faculty engaging in blood and marrow research. The first three researchers completed their work for...
VISIBLE HEART® LABORATORY

In 1997, Paul A. Iaizzo founded the Visible Heart® Laboratory (VHL) in collaboration with Medtronic, Inc. to study reanimated large mammalian hearts (including human hearts) under simulated physiological conditions. Since then, VHL has grown into a unique place to perform translational research from tissue studies to whole organ investigations. The laboratory also maintains a human heart image library which can be utilized by students, academicians, and individuals in the medical device industry.

In the past year, two new initiatives expanded VHL’s outreach and research scope:

• The Care Print Program, working in conjunction with University physicians Greg Helmer and Robroy McIver, aims to generate 3D models of hearts (using CT and MRI images) from complex clinical cases within 48 hours of a request. These models, which can be up to four times the size of the actual heart, enable surgeons to get a close-up look at abnormalities prior to surgery and even to perform implant studies with potential devices. This program was used 20 times in the past year.

• Using donated TransMedics organ care system units (OCS), VHL studied over 30 sets of lungs to develop ways to optimize perfusion and to keep them viable for transplantation. Since the beginning of these studies, VHL has extended the viability of lungs from 8 to 24 hours, which extends the geographic range for donated lungs over 600 miles by road or thousands of miles by plane.

For 2016-17, Iaizzo plans to make full use of new Transplant Research space (see sidebar) by expanding VHL’s studies of heart and lung preservation. In particular, he hopes to develop a cardiac preservation system akin to the OCS machines for lungs. Iaizzo also expects to add research capacity to VHL by adding new assistant professors and research scientists who will also teach at the University and perform outreach education.

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2015-2016 HIGHLIGHTS

• Acquired six new 3D printers, including both Makerbot and Uprint units that can print both heart models and prototype medical devices
• Opened the Transplant Research space, a 630 square foot facility adjacent to VHL
• Published the third edition of the Handbook of Cardiac Anatomy, Physiology, and Devices, a text used throughout the country in academia and industry. The new edition includes contributions from seven IEM members.
• Published a new edition of the Medical Device Innovation Handbook in conjunction with Professor William Durfee and IEM’s Medical Devices Center.
The Cancer Animal Core (CAC) is a facility for engineering faculty who have limited experience using animals in cancer research. It provides basic care to study animals (mostly rats and mice), develops and maintains cancer cell lines, induces and monitors tumors, prepares animals for testing, maintains data sets, and ensures compliance with the University’s Institutional Animal Care and Use Committee (IACUC). CAC supports both small experiments meant to generate preliminary results and long-term studies involving a large numbers of animals. Nearly all of the lab’s work falls under three categories: imaging, cancer therapeutics (including focal therapies and nanotherapies), and cancer management.

CAC has seen demand for its services nearly double in the past year. The rise in work for the lab has translated into increased educational opportunities for students (both graduate and undergraduate) and collaborative opportunities for faculty and local medical device companies.

Director John Bischof expects CAC to continue to expand its reach in 2016-17, noting an increase in interest from industry and from multi-faculty collaborative teams. Bischof also notes that growing interest in immunotherapy-based cancer treatments is increasing demand for the kinds of robust animal models that CAC provides.

The IEM Cancer Animal Core is managed by Qi Shao, a University of Minnesota graduate and current research associate in the Department of Mechanical Engineering, and scientist in IEM.

**2015-2016 HIGHLIGHTS**

- Supported translation research projects for two major medical companies and small studies for multiple local companies
- Hired two Master’s students from the Mechanical Engineering Department to assist with research, technical support, and lab management.
- Helped Prof. Samira Azarin secure a $400,000 Falk Transformation Award to study new techniques for treating metastatic cancers.
- Supported six University faculty research projects, all IEM members.
IEM’s 3D Modeling and Printing Core was recently established to provide training and other technical resources for students and faculty using the 3D printers in the Medical Devices Center, the Visible Heart Lab, and the new CSE Student Workshop. This new Core will be led by Prof. William Durfee, longtime IEM member and Professor and Director of Design Education in the Department of Mechanical Engineering.

The Core, which grew out of the Visible Heart Lab’s new Care Print Program (see p. 25), is geared to University clinicians and professors who want to develop patient-specific devices and models from images such as MRIs and ultrasounds. These devices and models will be used for education, clinical decision-making, and a wide variety of medical research projects. One application, for example, might be printing device prototypes for analysis and testing. Another might be printing an enlarged version of a segment of pediatric anatomy so that it is easier to study.

This new Core is, in many ways, a response to increased demand. 3D printing is now a “mainstream” technology in universities and industry, but the cross-disciplinary skill set needed to take advantage of 3D printing tools is still hard to find. According to Durfee, moving from 2D images to a useful 3D model takes a lot of specialty software, medical knowledge, and experience with the sophisticated machinery of 3D printers. By providing more training and printing capabilities to university clinicians and researchers - and, importantly developing new training and capabilities as 3D printing technology continues to advance - IEM ensures another way of fulfilling its mission of improving patient outcomes through engineering expertise.

“A congenital heart model generated from a clinical CT and printed as a blood volume model. These models were used for pre-procedure planning and for discussion with the patient’s family about the potential risks associated with the procedure.”

“A 3D model of a patient’s ascending aortic anatomy generated from a clinical CT scan. Transcatheter valves of various sizes were placed within the model to determine the relative positioning dislodgement forces.”

“Printing and painting a heart in 3D actually puts every nuance of that anatomy into your brain in a way you would never get just by looking at it.”

- Paul Iaizzo
IEM Member Recognition

DR. PATRICK ALFORD
Assistant Professor, Biomedical Engineering

Dr. Patrick Alford received an NSF CAREER award to study trauma-induced alteration of vascular smooth muscle mechanics. The CAREER award is given to the most promising early-career faculty who effectively integrate research and education.

DR. JOAN BECHTOLD
Professor, Orthopaedic Surgery

Dr. Joan Bechtold received the 2016 Orthopaedic Research Society Women’s Leadership Award.

DR. XIANG CHENG
Assistant Professor, Chemical Engineering & Materials Science

Dr. Xiang Cheng received a Packard Fellowship for Science & Engineering for his work on complex fluids in biological and physical systems.

DR. JAMES CLOYD
Professor, Experimental and Clinical Pharmacology

Dr. James Cloyd was named Mentor of the Year by University’s Clinical and Translational Science Institute.

DR. VIPIN KUMAR
Professor, Computer Science and Engineering

Dr. Vipin Kumar was named a University of Minnesota Regents Professor for his work in high performance computing and scientific data mining.

DR. THERESA REINEKE
Professor, Chemistry

Professor Theresa Reineke was inducted into the American Institute for Medical and Biological Engineering College of Fellows.

DR. RANDY SCHIESTL
IEM Industrial Advisory Board member

Dr. Randy Schiestl was elected a Fellow of the American Institute for Medical and Biological Engineering.

DR. CLIFFORD STEER
Professor, Genetics, Cell Biology and Development

Dr. Clifford Steer was named Associate Dean for Faculty Affairs for the Medical School.

DR. BOB TRANQUILLO
Professor, Biomedical Engineering

Dr. Bob Tranquillo received the 2015 Tissue Engineering International and Regenerative Medicine Society Senior Scientist Award for his contributions to understanding cell behavior, especially in cardiovascular and neural tissue engineering applications.
The 244 members of IEM represent many research specialties and sub-specialties. It is no surprise, then, that IEM members regularly appear in the media. Here are some examples of IEM members who shared their expertise on a variety of research topics in the past year:

Dr. Xiao-Hong Zhu’s research to explore potential treatment for concussions was highlighted in the Rochester Post Bulletin.

Dr. Roni Evans discussed the challenge of studying chronic pain’s impact on young adults in a story picked up by Associated Press, the Star Tribune, and MPR.

Dr. Karen Mesce’s research on enhanced neuron imaging technique was featured in eLIFE.

Dr. John Bischof discussed organ preservation in The Economist.

Dr. Paul Iaizzo’s research on Medtronic cardiac monitors measuring stress in bears was reported by BBC and other publications.

Dr. Paul Iaizzo discussed 3-D Printing in the Washington Post.

Dr. Andrew Grande's treatment of a painful nerve condition with surgery was profiled in the Hudson StarObserver.

Dr. Timothy Church and Dr. Douglas Yee discussed new breast cancer screening guidelines in Health Talk.

Dr. He’s mind-control technology was utilized in University of Florida’s first-ever drone race and featured in MN Daily and AP: The Big Story.

Dr. Kalpna Gupta’s research on the effectiveness of cannabis for pain was featured in MN Daily.

Dr. David Jacobs’ research showing that environmental contaminants in low doses can harm the brain featured in Environmental International.

Dr. Hubert Lim discussed the effectiveness of sound therapy with WCCO television news.

Dr. Gwenyth Fischer’s work as Director of the Pediatric Device Innovation Consortium was profiled by the Star Tribune.

Dr. Bob Tranquillo’s pediatric heart valve research was featured on KARE11 news and the Star Tribune.

Dr. Walter Low and Dr. Ann Parr discussed the relevance of fetal tissue to research in treating Parkinson’s and spinal cord injuries in the Star Tribune.

Dr. Kelvin Lim discussed traumatic brain injury’s psychological impacts and treatment strategies in MinnPost.

Dr. Jeffrey McCullough discussed the Zika virus in the New York Times.

Dr. David Jacobs Co-authored a study that links television watching and low levels of physical activity with lower cognitive function in midlife, published in JAMA Psychiatry.
Education and Outreach

ANNUAL SHORT COURSES

Advanced Cardiac Physiology and Anatomy - PHSL 5510

This short course provides an intense, one-week blend of lectures, demonstrations, and laboratory experience for graduate students, honor undergraduate students, and biomedical engineers from industry. It includes a daily gross anatomy lab using human cadavers, where small groups of students are guided through a detailed dissection of the human chest wall, thoracic cavity, and heart-lung blocs. In 2015-2016, 140 people attended this course.

A guest lecturer provides an overview of heart anatomy for PHSL course participants

A guest lecturer reviews dissection protocols for a group of PHSL course participants

Preservation of cellular therapies

This one-week course addresses the growing need to combine biopreservation with clinical practice. It covers the fundamentals of preservation, protocol development, storage facility design, regulatory issues associated with preservation of cell therapies, and clinical issues associated with biopreservation. Recorded lectures for this course are available online.

Preservation of molecular, cellular and tissue biospecimens

Over two days, students in this short course receive an overview of the science and practice of liquid-, cryo-, and desiccation-based biopreservation. It includes training in fundamental techniques, protocol development, documentation and validation, quality control, and regulatory issues.
The Third Annual IEM Conference and Retreat took place on September 21, 2015 at the McNamara Alumni Center, attracting a record crowd of approximately 400 participants. After a morning of superb keynote talks (see below) and an Industrial Fellowship induction ceremony, participants attended breakout sessions and poster presentations organized around IEM’s five research themes. The poster session also provided outstanding opportunities for networking and building collaborations.

**Plenary Session I: Ravi V. Bellmkonda**, Wallace H. Coulter Chair, Department of Biomedical Engineering, Georgia Institute of Technology, and President of the American Institute of Medical and Biological Engineering. “Biomedical Engineering: An Incubator for Disruptive Innovation in Health Research and Education.”

**Plenary Session II: K. Dane Wittrup**, C.P. Dubbs Professor of Chemical Engineering and Biological Engineering, Massachusetts Institute of Technology. “Tumor Immunotherapy with Targeted Cytokines: Theoretical and Experimental Investigations.”


**Plenary Session V: Brooks Jackson**, Vice President of Health Sciences and Dean of the Medical School, University of Minnesota. “The Importance of Interdisciplinary Collaborations between Health Sciences and Engineering.”

“We need to continually drive industry-University research partnerships, rethink education to prepare the future workforce, and cultivate an innovative and risk-taking culture.” -Grace Wang

“If we’re going to lead the way in increasing access to care and to delivering higher quality, more efficient care to all patients, we need to look beyond our own disciplines and find ways to tap into the ideas and talents across a wider spectrum.” - Brooks Jackson
The Otto Schmitt Distinguished Lecture Series, which is open to the public, is meant to engage discussions on grand challenges for engineering in medicine by national opinion leaders in research, industry, and government. The series is in honor of Dr. Otto Schmitt, a longtime University professor of biophysics, bioengineering, and electrical engineering who made significant contributions to a wide range of fields including submarine detection, electrocardiography, and quality of life measures.

IEM sponsored two Otto Schmitt Distinguished lectures during the 2015-2016 academic year.

In October 2015, Dr. Robert Nerem, Institute Professor and Parker H. Petit Distinguished Chair Emeritus of the Georgia Institute of Technology, a pioneer and world leader in bioengineering, presented “Engineering and Life Sciences: Celebrating the Past, Envisioning the Future” to an audience of over 180 students, faculty, researchers, and visitors. Dr. Nerem spoke passionately about the enormous contributions bioengineering research has made to better understanding biological mechanisms and improving clinical treatments. He particularly noted the importance of bioengineering to the study of blood flow, the development of new medical devices, and advances in regenerative medicine and stem cell technology. He also emphasized the growing importance of bioengineering to areas such as energy, the environment, and food.

In February 2016 Dr. Rick Horwitz, Executive Director of the Allen Institute for Cell Science, presented “The Allen Institute for Cell Science: Integrated and Multi-Scale, Spatial-Temporal Cell Biology” to over 100 listeners. Launched in 2015, the Allen Institute for Cell Science aims to create new directions and opportunities in cell science through mission-oriented, large-scale, multi-disciplinary team science. Dr. Horwitz briefly explained the history of the Allen Institute and introduced the Institute’s first project, which is to develop dynamic, visual data on cell organization and activities at multiple spatial and temporal scales. This data will eventually be used to create highly complex computational and predictive cellular models.
The Fourth Annual Minnesota Neuromodulation Symposium took place in April 2016. The program was organized and sponsored by IEM with major co-sponsors MnDRIVE Brain Conditions, the Center for Neuroengineering, Medtronic Neuromodulation, Boston Scientific, St. Jude Medical, Celveland FES Center, LivaNova, Rogue Resolutions, and the NSF IGERT Training Program. Other sponsors were Bio-Techne, Brain Vision, Neuroelectrics, IEEE’s Engineering in Medicine and Biology Society, and Medical Alley Association.

The Symposium brought together 483 scientists, engineers, clinicians, industrial practitioners, and entrepreneurs to discuss challenges and opportunities in neuromodulation. The agenda included nine plenary presentations; 10 highlight talks; two panel discussions featuring neuromodulation experts from leading institutions in academia, industry and government; and a poster and networking session to help participants exchange ideas in this exciting field.

A plenary speech, “Closing the DBS Loop in Parkinson’s Disease: The Promise and the Pitfalls,” was delivered by Peter Brown, a Professor of Experimental Neurology and Director of the Medical Research Council Brain Network Dynamics Unit at the University of Oxford.

Other plenary speakers included Philip A. Starr of the University of California, San Francisco, Bin He of the University of Minnesota, Grace Peng of the National Institute of Health, Carlos Peña of the FDA, Karen Moxon of Drexel University, Alvaro Pascual-Leone of Harvard Medical School, Jose C. Principe of the University of Florida, and Nitish V. Thakor of Johns Hopkins University.
Education and Outreach

CLINICAL IMMERSION

The Clinical Immersion program has been developed over the past few years with inputs from the IEM Industrial Advisory Board, and overseen by Associate Director for Education and Outreach, Paul Iaizzo. “Everyone has the same goal, but industry and academic groups come at problems from different angles,” says Iaizzo. “And of course they’re all really smart people with a ton of knowledge about medical devices, so when they spend structured and unstructured time together, all kinds of new and surprising things happen.” Even better, he says, “everything is local. Participants from industry can go home that evening, and we all start taking advantage of resources in our own backyards.”

IEM Assistant Director Ken Rosen, who leads the Clinical Immersion program, has been instrumental to implement the program since Fall Semester of 2015 with two, week-long groups focused upon surgery. The program has been expanded to include cardiology during the Spring Semester of 2016. The professionals who participated in these immersions represented the leading medical technology companies in the Twin Cities.

GOAL OF THE PROGRAM

“IEM developed the Clinical Immersion program for the purpose of serving our industrial colleagues, and enhancing academia - industry collaborations,” says Bin He, IEM Director. “It represents our commitment to work together with the medical device industry to seek engineering solutions for tomorrow’s medicine and health care.” The goal of the program is to help non-clinicians from industry – device designers, compliance experts, biomedical researchers, and others – develop an in-depth understanding of the clinical environment in which medical devices are used on a day-to-day basis. Participants in the program undertake a week long course observing surgeries, while receiving formal training in a clinical setting on processes, policies and procedures relating to a variety of healthcare situations. In the 2015-2016 year, over 60 industry professionals participated in either the surgery or cardiology immersion program.

“What I will take back to my work in Research and Development is a better understanding of how clinicians use various medical devices, how their teams function and how they make decisions, as well as the complexities of patient disease states.”
- Medtronic participant
A BUSY EDUCATIONAL WEEK

There is no such thing as a ‘typical’ clinical immersion day, as the observations depend on the cases that are admitted to the University of Minnesota Medical Center. Mornings tend to be filled with physician conferences, patient rounds, procedure observations, and meetings with residents, fellows and physicians for previews and debriefs about the day’s activities. Participants are encouraged to carefully observe workflow and patient flow so that they see how the entire clinical ecosystem works. Afternoons are generally spent by viewing additional procedures, touring special University facilities (like VHL and MDC), and a daily debrief session where the next day’s cases are presented.

The lunch hour between morning and afternoon activities is, in some ways, the most important part of the day as it provides an informal atmosphere to discuss the details of what they have seen during the morning. According to Ken Rosen, the informal lunch atmosphere “gives rise to lively conversation about new medical devices, research projects, potential product development partnerships, and all kinds of fruitful scientific insights. It’s where all the rounds, surgeries, and presentations come together and help everyone get a strong sense for medical technologies that can address unmet needs.”

“Members of my team returned to work with a whole new perspective on device development.”
– St. Jude Medical participant

LOOKING AHEAD

Based on enthusiastic feedback and industry interest, IEM is already planning Clinical Immersion weeks for 2016-17. According to Rosen, the University is uniquely positioned to bring together industry and clinical professionals: “We have a large and vibrant medical industry in the Twin Cities, and the University has top-notch clinical resources, from clinical experts to specialty labs right in the local industry’s back yard. Put these professionals together for a week in a busy academic hospital and everybody wins.”

“The value this program adds to my company’s goals for innovation: a better understanding of the customers and how to think outside of the traditional medical space.” – Boston Scientific participant
The IEM Seminar Series was launched in Spring 2015 to facilitate interdisciplinary collaboration among members of academia and industry in an informal environment. Talks are free and open to the public, and each presentation is followed by a question-answer session and time for networking. In addition, speakers from outside of the University of Minnesota meet with individual faculty members during their visits to discuss their research in more detail and explore possible collaborations. The IEM Seminar Series held 23 seminars in 2015-2016:

**September 2015**

**A.T. CHARLIE JOHNSON, PH.D.**  
Professor, Department of Physics and Astronomy  
Director, Nano/Bio Interface Center  
University of Pennsylvania  
“Graphene-enabled Nano/Bio Hybrids for Chemical Detection and Medical Diagnostics”

**MICHAE L MCALPINE, PH.D.**  
Associate Professor, Mechanical Engineering  
University of Minnesota  
“3D Printed Bionic Nanomaterials”

**NANYIN ZHANG, PH.D.**  
Associate Professor, Biomedical Engineering  
Penn State University  
“Understanding Brain Disorders using Translational Neuroimaging Approaches”

**October 2015**

**JONATHAN KUHN, PH.D.**  
Senior Principal Biomedical Engineer  
Medtronic  
“Opportunities and Challenges of Chronically Implantable Sensor Technologies”

**WARREN C. W. CHAN, PH.D.**  
Professor, Institute of Biomaterials & Biomedical Engineering  
Donnelly Centre for Cellular and Biomolecular Research  
Materials Science and Engineering  
Chemical Engineering, Chemistry  
University of Toronto  
“The Role of the Protein Corona in Mediating Nanoparticle Targeting”

**JENNIFER L. MUELLER, PH.D.**  
Graduate Director  
Professor Department of Mathematics, School of Biomedical Engineering  
Colorado State University  
“Electrical Impedance Tomography for Functional Pulmonary Imaging”

**STEVEN M. WRIGHT, PH.D.**  
Royce E. Wisenbaker II Professor  
Departments of Electrical and Computer Engineering, Biomedical Engineering, and Radiology  
Area Leader, Biomedical Imaging  
Texas A&M University  
“Research in High-Field and Parallel Imaging at the Magnetic Resonance Systems Lab”

**November-December 2015**

**ROY CHANTRELL, PH.D.**  
Professor, Department of Physics  
The University of York, United Kingdom  
“Computational Models of Magnetic Nanoparticle Hyperthermia”

**JOSE L. CONTRERAS-VIDAL, PH.D.**  
Hugh Roy and Lillie Cranz Cullen University Professor  
Dept. of Electrical & Computer Engineering  
Director, Noninvasive Brain-Machine Interface Systems Lab  
University of Houston  
“Restoration of Whole Body Movement: Recent Advances in Non-surgical Brain-machine Interface Systems”

**QI ZHAO, PH.D.**  
Assistant Professor  
Department of Electrical and Computer Engineering  
Department of Ophthalmology  
National University of Singapore  
“Visual attention in humans and computers”

**PAOLO BONATO, PH.D.**  
Department of Physical Medicine and Rehabilitation, Harvard Medical School  
MGH Institute of Health Professions, Harvard Medical School  
Wyss Institute for Biologically Inspired Engineering, Harvard University  
“Mobile Health Technology and the Clinical Management of Patients with Chronic Conditions”
January-February 2016

OLLI GRÖHN, PH.D.
Professor of Biomedical NMR
Vice director of A.I. Virtanen Institute
University of Eastern Finland
Kuopio, Finland
“MRI of brain damage and plasticity in experimental models of traumatic brain injury and epilepsy”

JÜRGEN KONCZAK, PH.D.
Professor
School of Kinesiology, Director of Graduate Studies
Director, Center for Clinical Movement Science
University of Minnesota
“Robotic Rehabilitation and Human Motor Control: Challenges and Opportunities”

SUHASA B. KODANDARAMAIAH, PH.D.
Benjamin Mayhugh Assistant Professor
Mechanical Engineering
University of Minnesota
“Robotic Tools for Observing Neural Computations in Intact Brains”

ERIC S. RICHARDSON, PH.D.
Director, Global Medical Innovation (GMI) track in the Master of Bioengineering (M.B.E.) program
Department of Bioengineering
Rice University
“Developing Medical Technology Solutions in, for, and with Emerging Markets”

March 2016

JEFFREY CHALMERS, PH.D.
Professor, Department of Chemical and Biomolecular Engineering
Director, Analytical Cytometry, Shared Resource
The Ohio State University Comprehensive Cancer Center
“Separation/Isolation of cells, from fundamentals to applications including T cells, hematopoietic stem cells to mature RBCs, and rare cells in blood, including circulating tumor cells”

RAJEV CHAUDHRY, M.B.B.S., M.P.H.
Consultant Primary Care Internal Medicine
Associate Professor, Department of Medicine
Medical Director, Technology, Center for Innovation
Co-Director, Knowledge and Delivery Center,
Office of Information and Knowledge Management
Mayo Clinic
Rochester
“Reengineering Primary Care at Mayo Clinic”
People, Processes and Technology

LINDA CARPENTER, PH.D.
Professor of Psychiatry and Human Behavior
Brown University
“Technology meets Psychiatry: Transcranial Magnetic Stimulation (TMS) Therapy for Neuropsychiatric Disorders”

KEITH R. THULBORN, PH.D.
Professor of Radiology, Physiology & Biophysics
University of Illinois
Chicago
“Why Spatially Resolved Biochemistry is Every (Electrical, Computer Science, Mechanical and Biomedical) Engineer’s Dream”

April-May 2016

ANTONIS A. ARMOUNDAS, PH.D.
Assistant Professor of Medicine
Harvard Medical School
Massachusetts General Hospital
“A Translational Approach to Probe the Pro/Anti-Arrhythmic Potential of the Heart”

FLAVIO FROHLICH, PH.D.
Assistant Professor
Departments of Psychiatry, Cell Biology and Physiology, Biomedical Engineering, and Neurology
Neuroscience Center
School of Medicine
University of North Carolina at Chapel Hill
“Engaging Cortical Oscillations: Rational Design of Non-Invasive Brain Stimulation”

D.S. FAHMEED HYDER, PH.D.
Professor, Radiology & Biomedical Imaging
Professor, Biomedical Engineering
Technical Director, MRRC preclinical scanners
Program Director, QNMR Core Center
Yale University
“Metabolic Dialectics in Biomedical Neuroimaging”

A. VANIA APKARIAN, PH.D.
Professor of Physiology
Northwestern University, Feinberg School of Medicine
“Mechanisms of Chronic Pain”

Students gather in Nils Hasselmo Hall over lunch for a weekly seminar
2016 marked the 15th Annual Design of Medical Devices Conference, the largest medical device conference in the world. The event brings together world-class medical device designers, researchers, and manufacturers from academia, government, and industry. Participants share perspectives and innovations in medical device design, and IEM and the Medical Devices Center are able to showcase the University of Minnesota as a leader in the medical device community and raise funds to support medical device education at the University.

The event has become so large that it is now staged in three locations: the Commons Hotel, McNamara Alumni Center and TCF Bank Stadium.

The 15th Anniversary edition was a huge success and included:

- More than 1,200 attendees from 17 countries
- 173 speakers and more than 110 posters
- 287 different entities represented (107 non-industry and 180 industry)
- 37 sponsors whose funding supports medical device education at the University

A key aspect of this year’s event was its Emerging Technology Forum “3D Printed Bionic & Medical Devices.” 3D printing experts from the US Food & Drug Administration, Worell Inc., University of Michigan, University of Louisville Hospital, Drexel University, and Tsinghua University all contributed to the Forum.

The Keynote Speakers included Dr. Manny Villafaña, Founder of St. Jude Medical, Cardiac Pacemakers, Inc. (now a major unit of Boston Scientific), ATS Medical (acquired by Medtronic), and several other companies that eventually went public. Dr. Villafaña’s inspiring talk about his career fully captured the innovative spirit of this event.
Sponsored by IEM’s Medical Devices Center and directed by Dr. Joe Hale, the Innovation Fellows Program is a full-immersion educational and medical device development program. The Innovation Fellows learn about FDA requirements, insurance reimbursement, intellectual property, prototyping, business strategies, and other complexities of the concept-to-market process while developing medical devices for a broad variety of clinical areas. Since the program’s inception in 2008, Innovation Fellows have generated over 180 invention disclosures, 77 patent applications, five start-up companies, eight licensed technologies, and post-fellowship employment at start-ups, leading medical technology companies, and academic institutions.

ADAM BLACK, PH.D.
After earning an Electrical Engineering degree and serving in the U.S. Army National Guard, Adam developed algorithms for analyzing large datasets of electrical and hemodynamic data at Medtronic’s Cardiac Rhythm Disease Management unit. Adam went on to receive his Ph.D. in biomedical engineering from the University of Minnesota, where he investigated structure and neural activation in various biological samples.

AMIT GOYAL, M.D.
After earning a BA in Economics from the University of Virginia, Amit received his medical training at Georgetown University and joined the University of Minnesota’s Department of Neurosurgery as a resident. His research and clinical interests focus on complex spine pathology, cerebrovascular disease, and skull base surgery.

MICHAEL GREMINGER, PH.D.
Michael received his Ph.D. in Mechanical Engineering from the University of Minnesota in the area of microrobotics and computer vision. He is currently an assistant professor of Mechanical and Industrial Engineering at the University of Minnesota Duluth, where he teaches courses in CAD/CAM, finite element analysis, machine design, and machining.

BRIAN KROHN, PH.D.
Brian recently completed his Ph.D. in Environmental Science from the University of Minnesota, where his research focused on analyzing possible development pathways and policy support for sustainable biofuels. He is a co-founder of a number of entrepreneurial projects, ranging from supplying local hops to Minnesota craft breweries to a successful health app that provides high quality fitness instruction.

STEVEN REINITZ, PH.D.
Steve is a graduate of Dartmouth’s first-in-the-nation engineering Ph.D. Innovation Program and a veteran researcher in the Dartmouth Biomedical Engineering Center’s orthopaedic implant retrieval program. He has co-founded three companies, one of which was a finalist in the 2013 MassChallenge competition, winning him a place in their four-month accelerator program.

AHMED SELIM, M.D.
Before joining the Innovation Fellows program, Ahmed studied medicine at the University of Alexandria in Egypt, worked as a cardiac research fellow at Albert Einstein College of Medicine in New York City, and was an assistant professor of Internal Medicine at the University of Iowa. He has worked on a device to improve survival in cardiac arrest patients and currently focuses on developing new devices for pulmonary hypertension and sleep apnea.

BRADLEY SLAKER, MBA
Brad is a successful product development professional with over 25 years of experience in all aspects of medical device realization. He has successfully developed and commercialized medical devices for the orthopedic, cardiovascular, urology, and neurology markets. Through DesignWise Medical, a non-profit organization he founded, he has helped guide the development of dozens of pediatric medical devices and procedures.

ANASTASIA ZINK, PH.D.
Anastasia completed her Ph.D. in Neuroscience at the University of Minnesota, where she explored brain mechanisms that contribute to obesity. She has also conducted research on neurodegenerative conditions of Alzheimer’s disease, Muscular Dystrophy, and Spinocerebellar Ataxia.

“The Innovation Fellowship combines intense clinical immersion and entrepreneurship training with access to unparalleled talent in engineering and medicine.” - Anastasia Zink
INDUSTRIAL FELLOWS

IEM’s new Industrial Fellows program grew out of a conviction that University faculty, facilities, and clinical capabilities were underutilized resources, especially in a region with a well-developed and active biomedical industry. More than an advisory group, the IEM Industrial Fellows help IEM understand the needs of local industry and establish new University research collaborations with local medical companies. Several Fellows were instrumental in developing the highly successful Clinical Immersion program (see p. 32), serving as ambassadors for recruiting initiatives within their organizations, and promoting IEM seminars (see p. 36), IEM Neuromodulation Symposium (see p. 35), and IEM Otto Schmitt lectures (see p. 34) to cultivate stronger ties between industry and academia.

DR. CYNTHIA THATCHER CLAGUE
Director of Research and Advanced Technology, Medtronic

DR. TIMOTHY DENISON
Senior Director of Core Technology and Neuromodulation Fellow, Medtronic

DR. BRUCE FORSYTH
Research Fellow, Boston Scientific

DR. GARY HANSEN
Director of Scientific Affairs, RespirTech

DR. BRUCE KENKNIGHT
VP, Emerging Therapies, Cyberonics/Valtech

DR. DAVID KNAPP
Vice President, Corporate Research, Boston Scientific

DR. JAYDEEP KOKATE
Senior Research and Development Fellow, Boston Scientific

DR. SUPING LYU
Senior Principal Scientist and Technical Fellow, Medtronic

MR. RICK MCVENES
Senior Director of Therapy Systems Research, Medtronic

MR. ERIC RUDIE
Founder and Chief Technology Officer, DenerVX
FELLOWSHIP PROGRAMS

Scott D. and Susan D. Augustine Biomedical Engineering Research Fellowship

The MD/MS dual degree program in biomedical engineering at the University of Minnesota provides top-ranked medical students with graduate training in biomedical engineering. To help strengthen this program, University of Minnesota alumni Dr. Scott and Susan Augustine contributed $1 million in 2004 for the establishment of the Scott D. and Susan D. Augustine Biomedical Engineering Research Fellowship fund. This fund supports annual fellowships for students pursuing an MS degree in biomedical engineering who have earned an MD degree or are enrolled in the University of Minnesota Medical School. The payout from this fund is matched on a dollar-for-dollar basis by the University’s 21st Century Graduate Fellowship Endowment.

The 2015-2016 Scott D. and Susan D. Augustine Biomedical Engineering Research Fellowship recipient is:

MIIRAM SMETAK
Miriam Smetak has a BS in Aerospace Engineering and a BA in Interdisciplinary Archeology from the University of Southern California and is working under Dr. Hugh Lim at the SONIC lab. For her fellowship program, she will assist Dr. Lim investigate and develop new neuromodulation techniques for treating tinnitus and hyperacusis.

Interdisciplinary Doctoral Fellowship

The Interdisciplinary Doctoral Fellowship (IDF) is awarded to outstanding graduate students with interdisciplinary dissertation topics who would benefit from interaction with faculty at one of the University of Minnesota’s interdisciplinary research centers or institutes. IEM is pleased to be one of the host sites for the Graduate School’s IDF and offers additional funds to support professional development as well as space to accommodate the needs of IDF research projects.

YULONG LI
Electrical Engineering
Advisor: Steven Koester
Research Center: Institute for Engineering in Medicine
Faculty Mentor: Bruce Gerbi
“Ultra-Small Fully Depleted Silicon-on-Insulator Device for in vivo Radiation Dosimetry”
MEMBERSHIP BREAKDOWN

IEM is comprised of 244 faculty members who serve in more than 63 academic departments and represent ten University of Minnesota colleges. Benefits of IEM membership include access to research funding provided by IEM, participation in organized research groups, assistance in developing contacts or collaborations within the University and with local industry, reduced costs for attendance at IEM-sponsosred conferences and activities, and reduced costs for use of IEM-sponsored research centers. IEM members can also apply for support for presenting at conferences or symposia, use of IEM equipment or facilities, sponsorship of visiting scientists or lecturers, and graduate student research.

Membership Representation
By Theme

IEM continues to grow and increase its engagement with faculty, students, clinicians, and professionals in industry and government. Over the past 3 years, IEM has seen a 61% growth in its overall faculty membership. Much of this growth indicates the increasing awareness of IEM among University clinicians and their interest in cross-disciplinary research collaborations.
IEM By The Numbers

IEM members occupy several top honors at the University of Minnesota, in recognition of outstanding research activity, teaching and academic service pursuits.

**EXPERTISE**

- # Tenured Faculty: 128
- # Tenure-Track Faculty: 28
- # Regents Professors: 2
- # AHC Academy for Excellence in Health Research Awards: 5
- # Distinguished McKnight Professorships: 13
- # Distinguished McKnight Land-Grant Professorships: 7
- # Endowed Chairs: 29
- # Distinguished University Teaching Professorships: 4
- # Morse Alumni Distinguished Teaching Professorships: 2

Over the past five years, IEM members have worked with the Office of Technology Commercialization on a variety of invention disclosures (intellectual property or IP) that fall under the following criteria:

- Research has resulted in a new discovery
- IEM member plans to publish or present the discovery
- Funded research (federal or industry) has resulted in IP
- IEM member wants to send research tools or materials to another institution
- A company has contacted an IEM member and wants to learn more about the research
- IEM member wants to start a company based on technology

Over the past 4 years, the IEM Group Grant seed funding program alone has generated more than 50 times the return on investment in NIH funding for IEM group grant PIs and Co-PIs.

Over the past five years, IEM members have worked with the Office of Technology Commercialization on a variety of invention disclosures (intellectual property or IP) that fall under the following criteria:

- Research has resulted in a new discovery
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- IEM member wants to start a company based on technology

### Intellectual Property (IP) Disclosures by IEM Members

Jan 2011 - Dec 2015

<table>
<thead>
<tr>
<th>Year</th>
<th>IEM Members w/ Disclosed IP</th>
<th>Number of Disclosures</th>
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<tr>
<td>2015</td>
<td>15</td>
<td>61</td>
</tr>
</tbody>
</table>

**NIH-NCI-U54: $8.2M (8/17/16-7/31/21)**

David Odde (contact PI) and David Largaespada (a PI), and Paolo Provenzano (Core PI) and their colleagues were awarded “Center For Modeling Tumor Cell Migration Mechanics.” Between 2/1/13-1/8/15, Dr. Odde led 2 IEM group grants entitled, “Cell Engineering Approach to Dynamic Cellular Biomarkers for Poor Prognosis Cancers” totaling $105K for both years. Because cell migration is an important feature of higher-grade cancer, Dr. Odde and his team will develop and experimentally test a computer model for the mechanical dynamics of cell migration. The model will serve as a kind of “flight simulator” with which to design therapeutic approaches that disable the mechanical machinery driving cell migration and tumor spreading.

**NIH-NHLBI-R01: $3M (7/16-6/30/21)**

Brenda Ogle (PI) was awarded R01 grant, “Stem Cell Therapy For Myocardial Repair.” Dr. Ogle and her research team from the University of Alabama received an IEM exploratory award in 2014 in the amount of $24,530 that helped contribute to obtaining this external research award. “If successful, 3D printing of cardiac tissues will improve outcomes of acute cardiac injury and will inform prospects for generating intact organs.”
SUPPORT IEM

IEM supports multiple projects through funding programs that have a proven record of assisting researchers develop major research initiatives and making fundamental discoveries. Please help make a difference and bring engineering solutions to medical problems. Your tax-deductible gift can be made directly through IEM’s website.

If you would like to support the Institute in a different way or make a donation for a specific cause, please contact us at the phone number or email address below.

Thank you!

Correspondence:
IEM Office, 612-624-8483, iem@umn.edu
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