BME

BIOMEDICAL ENGINEERING AT VANDERBILT UNIVERSITY

2018 | 2019

NASHVILLE

Vanderbilt's hometown of Nashville is a vibrant, engaging city known proudly as "Music City, U.S.A." and one of the fastest growing areas in the Mid-South. The university's students, faculty, staff and visitors frequently cite Nashville as one of the perks of Vanderbilt, with its 330-acre campus located a little more than a mile from downtown.

Nashville's downtown features a diverse assortment of entertainment, dining, cultural and architectural attractions. The Broadway and emerging SoBro areas feature entertainment venues and an assortment of restaurants. North of Broadway lie Nashville's central business district, Legislative Plaza, Capitol Hill and the Tennessee Bicentennial Mall. Cultural and architectural attractions are found throughout the city.

Named America's friendliest city three years in a row, Nashville is a metropolitan place that exudes all the charm and hospitality one expects from a rapidly growing capital in the new south. *Fortune* magazine named Nashville one of the 15 best U.S. cities for work and family. It has ranked as the No. 1 most popular U.S. city for corporate relocations by *Expansion Management* magazine. GQ posted an article dubbing the city "Nowville." *The New York Times* has declared Nashville a new "it" city. CBRE ranked Nashville as the most rapidly growing small market for tech talent in the U.S. and Canada in their 2018 Scoring Tech Talent report.

The city proper is 526 square miles with a population of nearly 667,000. The 13-county metropolitan area population is more than 1.7 million, making it the largest metro statistical area in Tennessee. Major industries include tourism, printing and publishing, technology, manufacturing, music production, higher education, finance, insurance, automobile production and health care management.

Nashville is comfortable and affordable, beautiful and friendly. When we say "Welcome to Nashville," we mean it.

VANDERBILT

Cornelius Vanderbilt had a vision of a place that would "contribute to strengthening the ties that should exist between all sections of our common country" when he gave a million dollars to create a university in 1873. Today, that vision has been realized in Vanderbilt, an internationally recognized research university in Nashville, Tennessee, with strong partnerships among its 10 co-located schools, neighboring institutions and the community.

Vanderbilt offers undergraduate programs in engineering, the liberal arts and sciences, music, education and human development, as well as a full range of graduate and professional degrees. The combination of cutting-edge research, liberal arts education, nationally recognized schools of law, management and divinity, the nation's top ranked graduate school of education and a distinguished medical center creates an invigorating atmosphere where students tailor their education to meet their goals and researchers collaborate to address the complex questions affecting our health, culture and society.

An independent, privately supported university, Vanderbilt is the largest private employer in Middle Tennessee and the second largest private employer based in the state.

Cover photo and right. The new Engineering and Science Building houses several biomedical engineering labs, the Vanderbilt Institute for Nanoscale Science and Engineering and is about two blocks from Vanderbilt University Medical Center and medical research buildings.

BME

BIOMEDICAL ENGINEERING AT VANDERBILT UNIVERSITY

MESSAGE FROM THE CHAIR

While the field of biomedical engineering is of newer vintage than other engineering disciplines, 50 years represents a rich history. We are especially delighted to celebrate our annivesary at Vanderbilt University as the National Biomedical Engineering Society marks it's own milestone of 50 years.

The program was one of the first of its kind in the U.S. It began with two tenure-track faculty and nine affiliated faculty. By 1976 it had grown to 10 tenure-track faculty and nine affiliated faculty, with research focused in five areas: application of transport and chemical kinetic theory to biological systems; analysis of bioelectric phenomena; quantitative kinesiology and skeletal muscle mechanics; biomedical instrumentation and computing; and radiological science.

Today, the department includes 21 tenured and tenure track faculty, three teaching faculty, 16 research faculty, and 51 affiliated faculty. Six primary faculty hold endowed chairs, and another three hold named faculty fellowships. We remain a leader in radiological/imaging science and excel in molecular and cellular bioengineering, nanotechnology, biophotonics, and surgical technologies.

Throughout its 50-year history, Vanderbilt BME has been defined by its proximity (a pleasant five-minute walk) from a major medical school and medical center that serves a five-state region and is ranked 8th in the nation in NIH funding.

It has been a great year for faculty and student achievement and recognition. Brett Byram received a NSF CAREER Award to develop a new ultrasound helmet for brain imaging. Craig Duvall was named a Chancellor Faculty Fellow (one of 10 at Vanderbilt) and was elected a Fellow of the American Institute of Medical and Biological Engineering. We now have 13 AIMBE Fellows among our primary faculty and another nine Fellows among our affiliated and emeritus colleagues. Anita Mahadevan-Jansen was elected as a Fellow of the Optical Society (OSA). Last fall, Cindy Reinhart-King was elected as a Fellow of BMES, the fifth BMES Fellow from Vanderbilt University.

In other news, we are pleased to welcome two new faculty. Audrey Bowden, an associate professor joining us from Stanford University, works in the areas of biophotonics and point-of-care medical devices. Mika Rubinov, a computational neuroscientist working on the brain "connectome," comes to us from the Janelia Research Campus of the Howard Hughes Medical Institute.

Prospective students, and more commonly the parents of these students, often ask where our BME students land after graduation. Among our Class of 2017 graduates, about 60 percent entered the workforce at companies such as Abbott, Medtronic, and St. Jude Medical. Another 20 percent went to graduate or professional school at institutions such as Johns Hopkins, Stanford and the University of Michigan. Ten percent went to medical school at institutions such as Vanderbilt, Washington University in St. Louis, and Texas A&M. Another 10 percent chose post-college paths that include activities such as military service, religious missions and non-profit work.

Nashville is an exciting city and Tennessee's largest. Fitting for Music City, we've formed a Vanderbilt BME faculty and student band. Sports fans have four professional teams to follow: the Tennessee Titans (NFL), Nashville Predators (NHL), Nashville Sounds (AAA baseball), and the Nashville Soccer Club (a USL team, transitioning to MLS in 2020). A robust food scene includes our famous hot chicken, Michelin-starred chefs, and ethnic eateries of every kind.

We invite you to celebrate with us at the annual BMES conference in Atlanta and at a special open house reception during homecoming weekend. Follow us on Twitter (@VandyBME and @VUengineering) and learn about the latest bioengineering news via *Cellular and Molecular Bioengineering*, the official BMES journal based here (@CMBEjournal). Finally, we greatly appreciate the support we receive from friends and alumni through our giving web link, vu.edu/supportbme.

Michael R. King
J. Lawrence Professor
Chair, Biomedical Engineering

Vanderbilt University School of Engineering

Vanderbilt University School of Engineering is internationally recognized as a leader in engineering research and education. Its faculty expertise and graduate programs are aimed at solving complex societal problems through collaborations among the disciplines and across campus. That culture of collaboration provides endless opportunities for students and faculty from all disciplines to work in any of our nine core competencies.

We call them intellectual neighborhoods – big data science and engineering; biomedical imaging and biophotonics; cyber-physical systems; energy and natural resources; nanoscience and nanoengineering; regenerative medicine; rehabilitation engineering; risk, reliability and resilience; and surgery and engineering.

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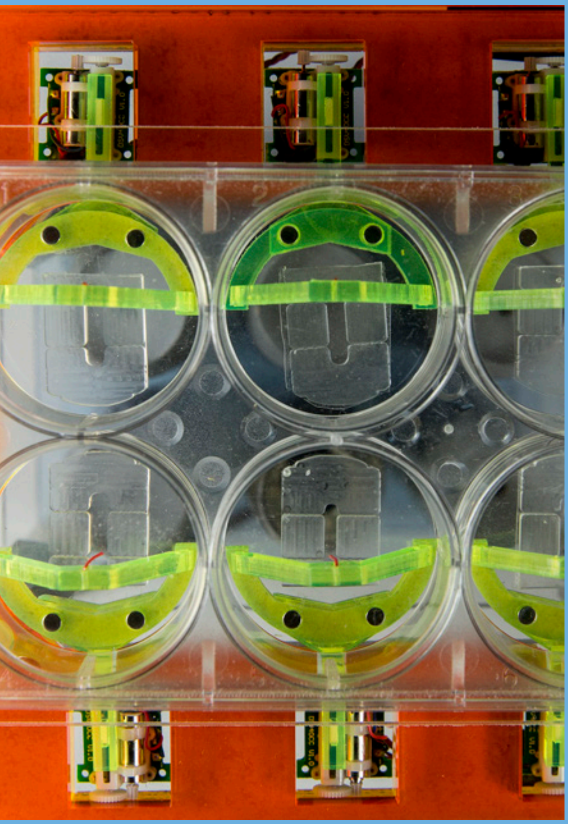
WIKSWO GROUP WINS R&D 100 AWARD AS TEAM DEVELOPS NEW ORGAN-CHIP EPILEPSY MODELS



The problem is significant: more than 60 percent of investigational drugs fail in human clinical trials despite promising early studies with research based on cell and animal models.

Miniature devices that use human tissue to closely mimic living human organs may well be the answer, an approach that demands sophisticated new tools as well as precisely tailored models using normal and diseased patient cells.

At the Vanderbilt Institute for Integrative Biosystems Research and Education, Gordon A. Cain University Professor John Wikswo and his team are blazing trails on both fronts.

A new device, created by Wikswo and colleagues and commercialized by a biotechnology spinoff from Oxford University, earned a R&D 100 Award in late 2017. The MultiWell MicroFormulator upgrades the 96-well plate, a widely used research tool, into an efficient, reliable and automated miniature lab of its own. A series of computer-controlled valves and pumps can mix and deliver minuscule amounts of drugs or other compounds into each well, allowing 96 experiments at one time.

"In contrast to bringing lots of well plates to a large and expensive high-throughput screening (HTS) robot, we are bringing a small and low-cost robot to each well plate," said Wikswo, also a professor of biomedical engineering and A. B. Learned Professor of Living State Physics.

"This is an excellent example of translational research," Wikswo said.

Already, CN Bio Innovations Limited, which licensed the Vanderbilt technology, is working with AstraZeneca to validate the new research tool, which enables HTS of multi-drug dosing regimens. Multi-drug therapies with two or more medications are increasingly used to treat infectious disease, chronic diseases and cancer but are extremely difficult to control and test.

Evolving "organ-on-chip" and "tissue-on-chip" research holds great promise in speeding up drug development and getting effective, safe treatments to patients more quickly. But creating more accurate disease models is the first step.

To that end, Wikswo and his group are developing organ-on-chip models for two genetic forms of pediatric epilepsy. The team will use two other tissue chip systems they created to develop models of tuberous sclerosis complex and DEPDC5 associated epilepsy, which both produce brain and heart abnormalities. One system reproduces the blood-brain barrier; the second system is a platform that uses engineered cardiac tissue to duplicate responses of the human heart.

For the work the group received a two-year, $2 million federal grant from the National Center for Advancing Translational Sciences, part of the National Institutes of Health. It was one of 13 tissue chip grants NCATS announced in September 2017.

"The excitement surrounding tissue chips is because they may streamline the development of new drugs, aid in the identification of toxic effects of drugs and environmental chemicals and provide new tools for understanding human biology and disease," Wikswo said.

The development of the MicroFormulator has been supported in part by NIH/NCATS (grant TR000491 to Vanderbilt University and contracts HHSN271201600009C and HHSN271201700044C to CFDRC) and through a research agreement with AstraZeneca UK Limited.

John Wikswo and his team win an R&D 100 Award for the MultiWell Microformatter, an automated miniature lab for organ-on-chip research.

Critical mass of biophotonics collaborators draws Bowden to BME

As a member of the Vanderbilt Biophotonics Center, Audrey Bowden joins a cohort of experts using light at different wavelengths to create better diagnostic tools and disease treatments.

"We live in a fantastic age where we have been able to harness the power of light," said Bowden, a new associate professor of biomedical engineering.

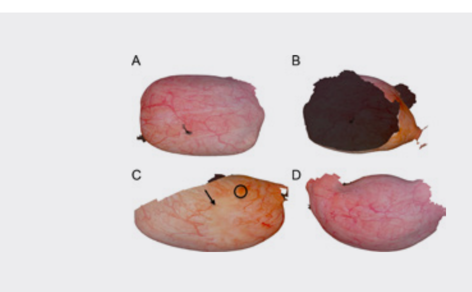
In presentations, she often uses a slide that lists parameters of light and the diverse information they provide. Optical wavelengths give us cellular resolution; spectra serve up biochemical information; scattering shows size distribution; absorption supports functional imaging; and polarization highlights anisotropy, or different properties in different directions – a factor of growing importance in brain research.

The power of the potential combinations is exciting, Bowden said.

"Even in its most simple and common form light is a very powerful way in which we interact with the world," she said. "Every living thing is emitting light even though we can't necessarily see it. It is a fundamental form of energy."

As an undergraduate, she came to optics through electrical engineering but was eager to move into more direct medical applications. Her arrival at Duke University for graduate study in biomedical engineering coincided with the opening of a new biophotonics center, and she worked in the same lab as some of her new Vanderbilt colleagues, including Kenny Tao, assistant professor of biomedical engineering.

Like Tao, Bowden at first focused on optical coherence tomography (OCT), a technique that captures 2D and 3D images of the retina and its components at the micrometer scale. Her dissertation involved a variation of OCT called spectral domain phase microscopy.



New process reconstructs high quality 3D bladder images with resolution that shows organ vasculature and necrosis. The dark area in figure B shows the bladder interior.

Bowden comes to Vanderbilt from Stanford University where her lab advanced OCT and its derivatives for projects related to imaging for bladder and skin cancer, early infertility, and ear, nose and throat conditions. She also has explored non-imaging projects involving portable point-of-care medical technology.

Recent work includes extracting quantitative information from image data with new theory, algorithms, calibration targets and system configurations. A 2017 paper published in *Biomedical Optics Express*, for instance, demonstrates a new method for generating high-quality 3D reconstructions of the bladder wall for use in bladder cancer evaluation and surgery planning within the standard imaging workflow.

Prior to Stanford, she spent one year with the U.S. Senate as a Congressional fellow and two years as a post-doc in chemistry and chemical biology at Harvard University. There, Bowden's work, which had Gates Foundation support, involved low-cost medical diagnostics and simple solutions with application across the world, especially remote, rural and resource-poor areas. She received a NSF Graduate Research Fellowship, the National Society of Black Engineers Graduate Student of the Year Award, the Arthur H. Guenther Congressional Fellowship and the Ford Foundation Postdoctoral Fellowship.

Vanderbilt was extremely attractive because "there are very few places in the country with a critical mass of faculty who work in the biophotonics area," she said. "I know many of the people here and I've watched their careers flourish.

"I'm a very collaborative person and there is value in community," Bowden said.

Rubinov combines algorithms with neuroscience insights to model brain activity

Mapping the brain – any brain, even one of a baby zebrafish – is a big task. Better, faster computers can handle larger data sets, but researchers like Mika Rubinov still run up against a paradox of functional imaging.

The human brain is big, with an estimated 100 billion neurons, but resolution of the imaging is poor and data sets are small. Zebrafish larvae brains are small, perhaps 100,000 neurons, but resolution is much higher, producing bigger data.

Navigating those tradeoffs is the work of Rubinov, a new assistant professor of biomedical engineering. His specialty is network analysis of the "wiring diagrams" of connections or activity in the brain.

Rubinov combines algorithmic development in network science with insights from cognitive and clinical neuroscience to model whole-brain structure and activity across species and scales, in healthy and diseased states. Rubinov joins the School of Engineering faculty after three years as a visiting scientist at Janelia Research Campus of the Howard Hughes Medical Institute.

But more data doesn't always mean greater understanding.

"Every year we have stronger computers and more advanced microscopes and more and more data," he said. "I think we have to be realistic about what we know and what we don't know."

With zebrafish, vertebrates that have similarities to human neural structure, we know more each day. Most recently, Rubinov and colleagues worked with high resolution imaging data of calcium changes within zebrafish stimulated to think they are swimming.

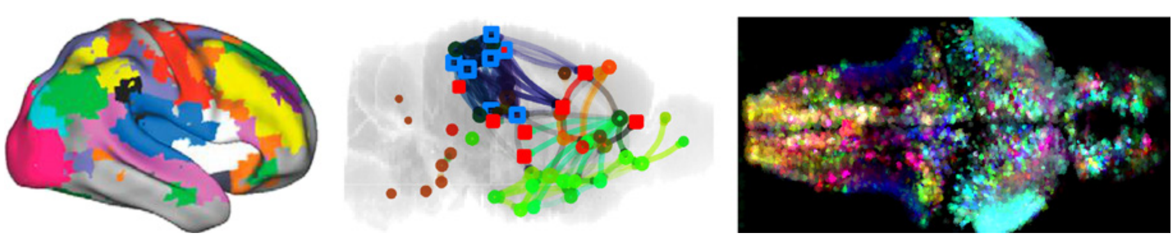
"Our data are at cellular resolution," Rubinov said.

Prior to his time at Janelia, Rubinov was a junior research fellow and research associate at the University of Cambridge in the Behavioral and Clinical Neuroscience Institute. Rubinov received a Ph.D. in systems neuroscience from the University of New South Wales in Sydney, Australia, and received the equivalent of an M.D. at the University of Melbourne.

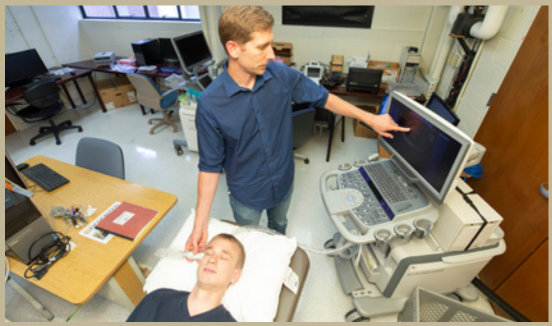
The department he joins already is heavily involved in brain imaging plus developing new diagnostic tools and techniques, as well as potential treatments.

"I liked the collegial atmosphere at Vanderbilt, and biomedical engineering is really the department where I feel at home. It has a heavy computational focus," he said. "This is a place where I could establish a very interesting research program."

Mika Rubinov uses functional imaging and algorithmic development to model interactions between regions of the brain and the strength of those connections, or networks.



ULTRASOUND HELMET WOULD ENABLE BRAIN-MACHINE INTERFACE AND LIVE IMAGES



Brett Bryam captures brain images for preliminary work toward building a ultrasound helmet and brain-machine interface.

Ultrasound technology for the brain could produce real-time images during surgery, identify where certain feelings or actions stimulate brain activity, and even create the ability to control software and robotics by thought.

Because basic ultrasound beams bounce around inside the skull, no useful imagery makes it out, and next-generation brain imaging has eluded medical doctors and scientists for decades.

Only now have the technologies aligned to make it possible, said Brett Byram, assistant professor of biomedical engineering.

With a $550,000 National Science Foundation Faculty Early Career Development award, Byram will use machine learning that gradually accounts for distortion and delivers workable images. He also wants to integrate electroencephalogram technology to show not only brain perfusion—how blood flow correlates to changes in thought—but also areas of stimulation related to movement and emotion.

"The goal is to create a brain-machine interface using an ultrasound helmet and EEG," Byram said. "A lot of the technology we're using now wasn't available when people were working on this 20 or 30 years ago. Deep neural networks and machine learning have become popular, and our group is the first to show how you can use those for ultrasound beamforming."

The applications, he said, are endless. At the basic level, it could allow for images at least as clear as those doctors are accustomed to seeing of the heart or uterus.

Going forward, a person with limited movement due to ALS could think about wanting a glass of water, and a robotic arm could retrieve one because the helmet detected blood flow and EEG information told it to. A student reading a paper may feel stress about a certain part that isn't properly sourced, and the computer would know to put a mark there for later editing.

Byram is working with Leon Bellan, assistant professor of mechanical engineering and biomedical engineering, and Michael Miga, Harvie Branscomb Professor and professor of biomedical engineering, radiology and neurological surgery, to develop the helmet. He plans to invite Vanderbilt University Medical Center doctors to the team as their work progresses.

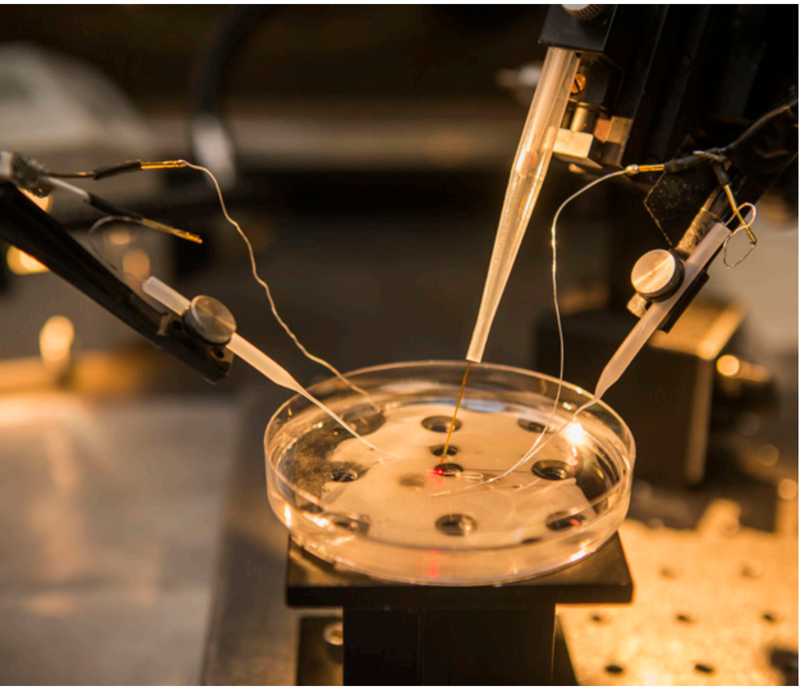
The prestigious five-year NSF grant – Ultrasound Brain-Computer Interface – began May 1, 2018.

"We expect the portable ultrasound helmet prototypes will resolve ultrasound image quality problems, and the new integrated algorithms will lead to new techniques for both understanding brain activity and using it to interact with computers," Byram said.

A wearable helmet will capture ultrasound and EEG signals together and a new probe will physically register both. The helmet data will be used to develop independent ultrasound only and integrated (EEG and ultrasound) algorithms for detecting brain states that computer systems can use either as direct commands or as input to adapt their behavior to a user's current brain state.

This work will be a transformational integration of acoustics, machine learning, signal processing, and neuroscience to better understand and access functional and anatomical information, he said.

Byram's Biomedical Elasticity and Acoustic Measurement Laboratory was formed in August 2013. The BEAM Lab is part of the Biomedical Engineering Department and affiliated with the Vanderbilt Institute for Surgery and Engineering.



Vanderbilt tech underpins $9 million NIH project to advance infrared treatment

Targeting specific areas of the nervous system – even single nerve cells – with light that can stimulate or inhibit electrical signals has promising application as treatment for common conditions such as cardiac arrhythmia, asthma, sleep apnea and even chronic pain.

"The potential impact is revolutionary and disruptive," said E. Duco Jansen, professor of biomedical engineering and senior associate dean of graduate education and faculty affairs. "We have a lot of engineering, physics and biology work to do before we're there, and that's why we're getting this level of funding."

Vanderbilt is one of three major universities involved in a four-year, $9 million NIH grant to develop and test infrared neuromodulation. Jansen and Anita Mahadevan-Jansen, Orrin H. Ingram Professor of Engineering, and Peter Konrad, professor of neurological surgery, developed the underlying technology for the research.

Unraveling the mechanisms in the nodose ganglion, a cluster of cells that send and receive signals through the vagus nerve to control heart rate, respiration, digestion and several other autonomous functions, is the Vanderbilt team's focus. First, Jansen and his group must determine which cells control which responses and then how to stimulate one without affecting the others—for instance, lowering blood pressure without inducing asthma.

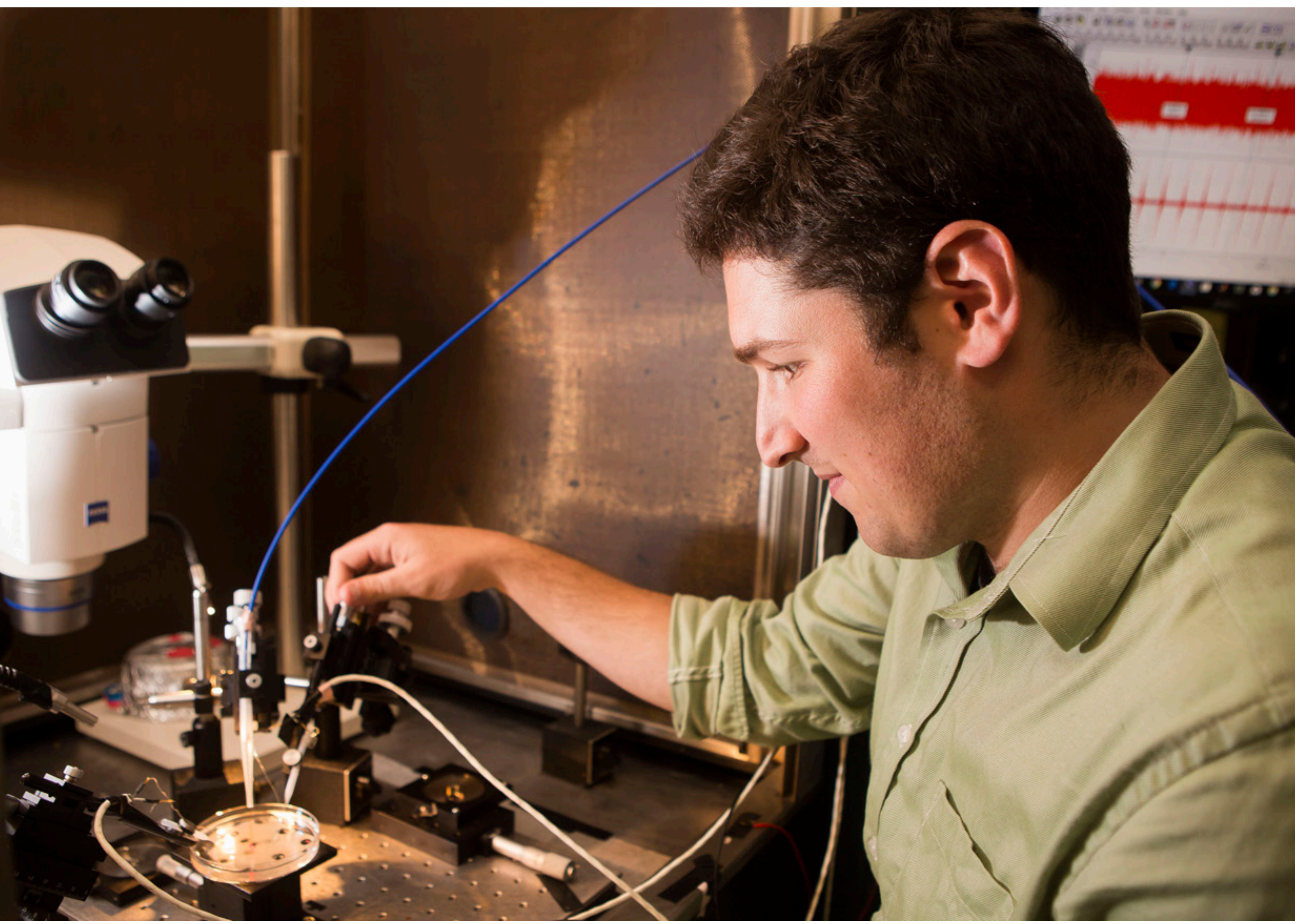
To do so, they will develop computational models that simulate the body's responses and also study the interaction of tiny laser pulses with the nerve cells, working towards systems to be implanted in patients.

As part of the foundational research, Jeremy Ford and Mohit Ganguly, both fifth-year biomedical engineering Ph.D. students, are optimizing the application of light to test pain inhibition in sea slug nerve clusters. They've been using different angles, pulsing and configurations of infrared light to monitor where and when an electrical single is blocked in slug neural tissue. Sea slugs and humans have similar pain-conducting neurons.

The idea of using minimally invasive, drug-free treatment to treat chronic pain has widespread appeal. Infrared neuromodulation has potential application as a treatment for other conditions, from high blood pressure to diarrhea.

The grant, made in 2017, is through the NIH's Stimulating Peripheral Activity to Relieve Conditions program. Case Western Reserve University School of Medicine is the lead institution, and researchers from the University of Pittsburgh also are involved.

Ph.D. student Jeremy Ford, **below,** blocks pain transmission in a cluster of sea slug neurons as part of a massive NIH effort to develop infrared neuromodulation treatments. A Vanderbilt team including E. Duco Jansen, **left,** developed the underlying technology.



FORMER PRO CYCLIST CHARGES AT SEPSIS WITH DIALYSIS-LIKE DEVICE

Sinead Miller, Ph.D. '17, has taken aim at sepsis. She's ready to produce and market a new device that clears bacteria from the blood through a process that resembles kidney dialysis. PATH EX, her company, has performed well in business accelerators and start-up competitions.

"Anyone could die from sepsis," said Miller, a former professional cyclist who earned her Ph.D. in biomedical engineering. "It is easy to find story after story about someone who had a minor cut, ended up with sepsis and died from it."

Raising capital and clearing regulatory hurdles for a Class III medical device is a long game, but Miller and PATH EX got out of the gate quickly.

She and Todd Giorgio, professor of biomedical engineering and Miller's research adviser, received a NSF Small Business Technology Transfer Phase I grant for $225,000 in 2017; word on the team's Phase II grant is pending.

PATH EX took top honors in the 2017 Louisiana Startup Prize, securing more than $70,000 in cash and business services. The company also took part in ZeroTo510 medical device accelerator and received a $50,000 equity investment from Innova Memphis, an early stage venture capital firm.

The company also received a $135,000 grant from Launch Tennessee and won another $15,000 in the agency's student pitch contest at a 36|86 event in 2017.

The device has a hollow channel thats uses centrifugal forces to separate sepsis from the blood, and then cleaned blood is pumped back into the patient. Miller has filed for provisional patents and is working with the Vanderbilt Center for Technology Transfer and Commercialization on intellectual property issues and Food and Drug Administration approval. Advisers at the Wond'ry, Vanderbilt's entrepreneurship hub, helped craft the initial business plan and pitch to investors.

The need for a reliable intervention is clear. Sepsis occurs when the immune system, already fighting one infection, malfunctions and causes bacteria to inflame the entire body. It's a leading cause of death in intensive care units — nearly half of all ICU patients who get it die — and it costs the U.S. health care system $24 billion annually to fight.

Preclinical studies have validated the technology, which demonstrated a reduction in bacterial concentration in the bloodstream by more than 95 percent in a single pass of contaminated blood.

"Many patients either succumb to sepsis or suffer serious sequelae before antibiotics can have their effect," said Dr. Julia Lewis, a nephrologist in the Vanderbilt Center for Kidney Disease with whom Miller consulted. "This device affords the opportunity to remove the damaging effects of sepsis immediately, affording patients a window to survive."

Miller knows a bit about survival. She was in a bicycle race, at the top of her game, a lifelong athlete with unrivaled discipline and drive, when a collision ended her career.

People say she hit a parked car. She can't remember.

"I lost consciousness for 25 minutes. I do not remember anything from that accident or six months thereafter," Miller said. "I sustained a traumatic brain injury, broke my nose, my jaw, bones in my face, my C3 and C5 vertebrae. I'm fortunate not to be paralyzed."

After a long rehabilitation, Miller turned her focus to research. She earned her Ph.D. in three years, starting with magnetic nanoparticles to bind to bacteria and pull it out of blood. It worked in small quantities, but countless computer models showed the approach lacked the force to scale to clinical use.

"Then I ran across some research using inertia to separate cancer cells from the blood. I knew bacteria was a different size from blood cells, so I started with that," she said.

The drive that fueled Miller's cycling career, then Ph.D. studies, is now focused on building PATH EX. Giorgio said he knew from their first meeting that Miller had the curiosity and focus to be successful.

"Later, it was clear she could combine her individual academic skills with an aptitude for interdisciplinary team science," he said. "Her devotion to entrepreneurship emerged more recently. With this combination, she's unstoppable."

Undergrads create 3D printed arm bones for surgery planning and training

Orthopaedic surgeons typically look at X-ray or CT images of a broken arm bone and hold up an old-school ruler to confirm the best plate type and size for repair.

But the process is not always that easy, especially in cases involving complex fractures. And without years of experience to inform their estimates, young surgeons may need more time in the operating room to get a good fit.

A team of biomedical engineering seniors set out to show how replicas of the damaged bones would streamline the process, creating 3D printed humerus bones from prior cases at Vanderbilt University Medical Center. The humerus is among the longest bones in the human body, and arm fractures account for 50 percent of broken bones in adults.

The team asked three surgeons to examine four pre-surgery versions of 10 humerus fractures: an X-ray, a two-dimensional CT scan, a 3D rendering and a 3D printed bone model. The retrospective study used complex distal humerus fractures that surgeons had repaired at VUMC.

James Ford, Rachel Howell, Ivy Lee, Annalee Schuck and Caroline Stiles, all BE'18, analyzed the results and hope to co-publish a journal article on their findings. For their two-semester senior design project the students worked with Dr. Donald Lee, professor of orthopaedic surgery and rehabilitation, and Dr. Sumit Pruthi, associate professor of radiology and radiological sciences and pediatrics. Pruthi helped establish the new 3-D Printing Center at Monroe Carell Jr. Children's Hospital at Vanderbilt, which serves both pediatric and adult cases.

Team members were attracted to a senior design project with direct patient impact. Ford, who heads to medical school next year, said a small amount of data can show clear differences, particularly in medial fractures.

In a separate case, the group printed a model of a complex scapula fracture before surgery.

"The surgeon was able to physically pick up the printed bone and move it around and fit the plates, even contouring them in advance before sterilizing it for surgery," Howell said.

BME students repair medical devices in Guatemala during spring break

A dozen Vanderbilt biomedical engineering undergraduates spent their 2018 spring break week in Guatemala, working alongside 30 engineering students and their professors from a Guatemala university to repair medical equipment at four hospitals.

It was the sixth trip with BME students since Associate Dean and Associate Professor of Biomedical Engineering Cynthia Paschal began offering the service learning course in 2008. The Vanderbilt students brought expertise in biomedical engineering and devices; the students from the School of Engineering at Universidad del Valle de Guatemala (UVG) brought a solid foundation in electronics and mechatronics.

In teams, they worked at four hospitals – Hospital Infantil de Juan Pablo II and INCAN, a cancer specialty hospital, both in Guatemala City; and Hospital Nacional Pedro de Bethancourt and Obras Sociales del Hermano Pedro, both in Antigua City.

Tori Qualls, Chad Keller and María Belén Hernández (UVG) repaired one of several infant incubators. Broken fan mounts had caused an awful noise and inability to evenly distribute heat. They proposed a fix and went shopping for parts – a rubber tie, a bit of glue, a few screws and, of course, duct tape. It worked.

Prior to the trip, students were assigned to find manuals for equipment they'd work on, assemble parts, and, for two students, devise a rigorous inventory system for Obras Sociales Del Hermano Pedro, which had collected equipment and devices in a central storage location after a recent renovation.

Two BME students – Seiver Jorgensen and Anna Word – worked on the tracking and inventory system before leaving Nashville. The hospital had a list of equipment but didn't know what worked and what didn't or what some of it was used for. It was a big job.

In two days the students categorized and, in most cases, tested 250 pieces of equipment, coding them by color for condition: green (working); yellow (needs repairs); red (trash); or blue (use for parts).

The Vanderbilt and UVG students complemented each other well.

"They are extremely skilled engineers and often knew things we didn't, so we made a good team. Most importantly, Dean Paschal was forming connections between del Valle's engineering program and each of the hospitals that we visited, trying to set it up so their engineering students could continue doing the work we started year-round," said Austin Hardcastle, BE'18.

Company co-founded by BME alumnus launches design platform for custom fit products

When it began, Standard Cyborg set out to make custom-fabricated orthotics and prosthetics easier and quicker – especially in parts of the world with limited medical resources where the needs are often the highest.

Cofounders Garrett Spiegel, BE '10, and Jeffrey Huber, a serial entrepreneur, did just that. Standard Cyborg's software is used across 23 countries on six continents. Thousands of patients have been helped through provider partnerships with private firms, non-profit companies, NGOs, governmental entities and research groups.

Forbes put the pair on its 2018 "30 Under 30" list in the health care category and Standard Cyborg, based in San Francisco, remains part of the well-connected Y Combinator community.

With a solid and growing customer base for its O&P software, Standard Cyborg has expanded its capabilities to support custom design of other products, such as shoe inserts, fracture casts, knee braces and more. The team has developed what Spiegel calls a "geometry engine," a platform that enables design of custom fit products for the body at mass scale.

Think of it as CAD software built for custom manufacturing. In standard manufacturing, designing a component make take hours or days or but that cost is spread over thousands or millions of units.

The design cost for a custom prosthetic socket or shoe insert or even a football helmet is another matter entirely. Hiring 50 CAD engineers to design custom pieces, even in two or three hours, is too costly for companies and customers. Every startup or established company that wants to produce affordable custom products slams against the same barrier, Spiegel said.

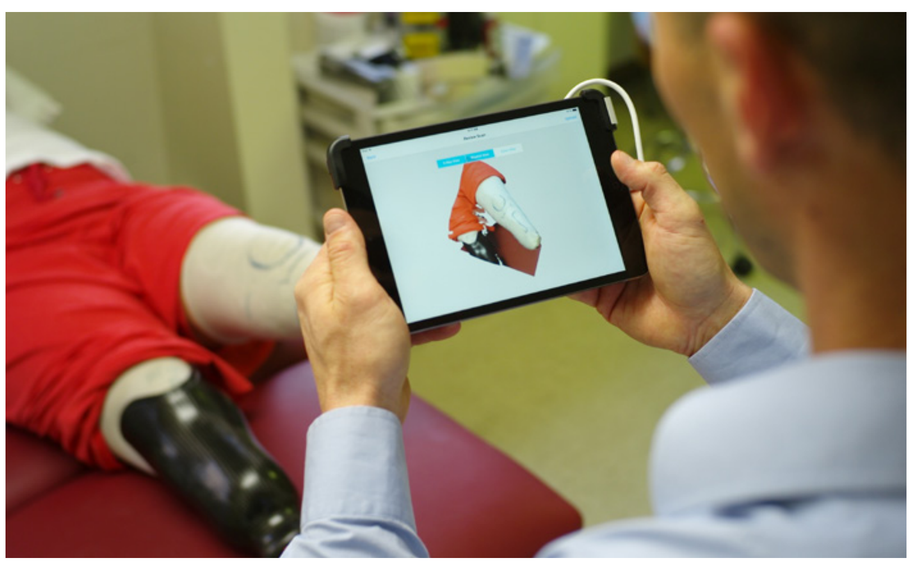
Now, with Standard Cyborg's new platform, designers can spend two hours on a product but save the work and automate changes so each additional piece takes seconds or minutes.

"We've created a generalized set of geometry tools that means companies don't have to reinvent the wheel," said Spiegel, who founded the Vanderbilt chapter of Engineering World Health as a biomedical engineering undergraduate. "This will be a system that removes a lot of hurdles. It is a big pain point."

The company's initial focus was on custom sockets because poorly fitted ones cause pain, sores and other complications. The software enabled providers to see multiple patients quickly, an asset for remote areas, and use a custom iPad app to take scans. Among the entities using Standard Cyborg's technology: The U.S. Veterans Administration; Doctors Without Borders in Jordan; the Range of Motion Project in Ecuador; LimbForge in Haiti; Baylor College of Medicine's Center for Global Initiatives in Sri Lanka and Tanzania; and the University of Michigan Biomedical Manufacturing and Design Lab.

For Spiegel, who is behind the company's software, it is familiar territory. At Vanderbilt, he made two trips to Guatemala as part of Associate Dean Cynthia Paschal's class on medical device design for developing countries. After graduating, he was a program associate in Global Health Technology at Rice University and then worked at D-Rev for more than three years.

"I was always interested in health care and improving people's health but I knew my skill set and interests wouldn't be the medical practitioner route," Spiegel said.



Standard Cyborg's software platform allows doctors in the field to take quick scans and create 3D models of prosthetic sockets and other O&P components – ideal for remote areas.

Austin Dirks, BE'08, right, and Stephen Saine, BS'04, are on a mission to streamline medical device procurement.

Alumni startup speeds hospital device and technology procurement

Three key experiences paved the way for Austin Dirks, BE'08, and Stephen Saine, BS'04 to launch a medical device and technology procurement platform together in July 2014.

Both attended Vanderbilt as undergraduates, both were in the School of Engineering, and both were members of Sigma Chi. Their "immediate affinity" accelerated the relationship and likely put GreenLight Medical on a faster track.

The company in August 2018 announced a partnership with symplr, a provider of health care compliance and credentialing platforms, creating an end-to-end vendor management solution for the health care industry.

"The process for introducing new products to a medical facility has completely transformed in the past five years," said Dirks, who is CEO. "By partnering with symplr, we protect the hospital with the first-of-its-kind application to manage both vendor credentialing compliance and new product request policy seamlessly."

More than 100 hospitals already were using GreenLight's platform to vet new devices and technology, getting important tools into the hands of physicians and other hospital staff more quickly. That is GreenLight's bottom line.

"Our mission statement is to get medical technology into a doctor's hands so he or she can use it to affect patient care," said Dirks, who majored in biomedical engineering at Vanderbilt, earned his MBA from Harvard Business School, and worked at St. Jude Medical in medical device sales and engineering.

At its most basic, GreenLight is a cloud-based value analysis program that brings vendors, hospitals and physicians together in a virtual space to speed up decision making.

Such decisions slowed to a frustrating and expensive crawl as old-school relationships between individual doctors and vendors gave way to hospital value analysis committees. Hospitals and health care systems formed the panels as concerns about health care costs mounted, and they review requests for new medical equipment, weighing the costs and benefits of each item.

That process can take up to a year. GreenLight has reduced the procurement cycle to 35-45 days by bringing people, documents, data and decisions together in a central dashboard.

The company has participated in several accelerator programs, including Healthbox, TMC Innovation Institute and Jumpstart Foundry. GreenLight also was one of 13 companies chosen to take part in Google Pitch Day 2017, and in September 2017 *Insights Magazine* named it among "the 10 most innovative procurement solution providers."

Biomedical Engineering Faculty

Front row: Mark Does, Michael Miga, Michael King, Amanda Lowery, Craig Duvall, Anita Mahadevan-Jansen, William Grissom, W. David Merryman **Back row:** Adam Anderson, Brett Byram, John Wikswo, E. Duco Jansen, Cynthia Paschal, Matthew Walker, Justin Baba, Rick Haselton, Franz Baudenbacher, Kenny Tao, Cynthia Reinhart-King **Not shown:** John C. Gore, Todd Giorgio, Art Overholser, Audrey Bowden, Mika Rubinov

Noteworthy

Grissom leads $2.6 million NIH project to enhance fMRI

Associate Professor of Biomedical Engineering William Grissom is the Principal Investigator on a $2.6 million basic research grant from the National Institutes of Health to combine new pulse and RF coil designs for improved, finer fMRI resolution.

The ambitious R01 project aims to overcome technical limitations and achieve higher quality imaging as small as 600 microns, or 6/10 of a millimeter. Ultra-high field MRI can detect brain activity in areas as small as 1 to 2 millimeters. But at such levels background “noise” from magnetic pulses compromises image clarity and accuracy.

Team to develop nanoscale inhibitor of key triple-negative breast cancer pathway

The National Cancer Institute has awarded a $465,000 R01 follow-up grant to a team co-led by Associate Professor of Biomedical Engineering Craig Duvall to develop a novel molecular therapy for triple-negative breast cancer.

Duvall and Rebecca Cook, assistant professor of cell and developmental biology at Vanderbilt School of Medicine, are co-Principal Investigators of the large, interdisciplinary team. Central to the study is targeting a complex known as mTORC2, part of the molecular pathway that drives cancer cell survival and chemotherapy resistance in this aggressive type of breast cancer.

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Junzhong Xu, Assistant Professor, Radiology*

Karl E. Zelik, Assistant Professor, Mechanical Engineering

*and Radiological Sciences

AWRDS AND HONORS SPOTLIGHT

FACULTY

Brett Byram, assistant professor, received a CAREER Award from the National Science Foundation.

Craig Duvall, associate professor, was named a Chancellor Faculty Fellow and was elected a Fellow of the American Institute of Medical and Biological Engineering.

Duco Jansen, professor and senior associate dean of graduate education and faculty affairs, received the Edward J. White Engineering Faculty Award for Excellence in Service.

Anita Mahadevan-Jansen, the Orrin H. Ingram Professor of Engineering, was elected as a Fellow of the Optical Society.

Michael King, the J. Lawrence Wilson Professor and Department Chair of Biomedical Engineering, received the 2018 *Cellular and Molecular Bioengineering* Most Downloaded Article Award for "Nanomaterials for the Capture and Therapeutic Targeting of Circulating Tumor Cells."

Cynthia B. Paschal, associate professor and associate dean was named University Marshal, the first female Marshal of the University.

Cynthia A. Reinhart-King, Cornelius Vanderbilt Professor of Engineering, was named a 2018 National Academies Inaugural New Voices Fellow, a 2018 Editorial Board Member of Biophysical Journal, and became a Standing Member of the NIH Cellular and Molecular Technologies Study Section.

John P. Wikswo, Jr., Gordon A. Cain University Professor, received a 2017 R&D 100 Award for the MultiWell MicroFormulator, selected as one of the 100 Most Technologically Significant New Products of the Year in the Analytical/Test category.

Zhenjiang "Jason" Zhang, research assistant professor in the King Lab, received the 2018 BMES Career Development Award.

AFFILIATED/ADJOIT FACULTY

Charles F. Caskey, assistant professor of radiology and radiological sciences, received the Frederic Lizzi Early Career Award from the International Society of Therapeutic Ultrasound.

Edward Chaum was named the Margy Ann and J. Donald M. Gass Chair in Ophthalmology in 2018, and Elected to Macula Society and the Retina Society.

Andre L. Churchwell, Levi Watkins Jr. Professor of Medicine, received the 2017 Pioneer in Diversity Award from Vanderbilt University.

Bruce M. Damon, associate professor of radiology and radiological sciences, was named a Fellow of the American Association for the Advancement of Science.

Dario J. Englot, assistant professor of neurological surgery, received a NIH Pathway to Independence (Independent Phase) Award, a Travel Award and the Reichert Award from World Society for Stereotactic & Functional Neurosurgery, Berlin. He was named a Fellow of the American Epilepsy Society and received the Kumar New Investigator Award from the North American Neuromodulation Society.

Stacy Klein-Gardner, adjoint associate professor of biomedical engineering, was selected as a member of the Academy of Fellows of the American Society for Engineering Education.

Karl E. Zelik, assistant professor of mechanical engineering, received the International Society of Biomechanics Promising Scientist Award and an American Society of Biomechanics Young Scientist Post-Doctoral Award in 2017, and was named a 2018 Nashville Emerging Leader. His laboratory also received the Wearable Robotics Association "Fan Favorite" Innovation Award.

OTHER DISTINCTIONS

Shawn Barton, a graduate student of Wellington Pham, received the Combining Clinical and Research Careers in Neuroscience Symposium Travel Award, to attend the National MD/PhD Student Conference in Keystone, Colorado.

John Dunbar, facilities manager, received the Judith A. Pachtman Staff Service Award.

Hernán González, a graduate student in the Englot Lab, received Best Poster Award and a Travel Fellowship Award at the North American Neuromodulation Society Annual Meeting in Las Vegas, Nevada.

Korie A. Grayson, a PhD student in the King Lab, received the 2018 BMES-NSBE Student Travel Award.

Sumeeth Jonathan, a graduate student of Will Grissom and Charles Caskey, received an NIH BRAIN Initiative Travel Award and a Best Student Poster Award for the International Society of Therapeutic Ultrasound.

Natalie Hawken, a student of John Wikswo, received a post-baccalaureate Intramural Research Training Award from NIH.

Julie Kohn, a graduate student in the Reinhart-King Lab, was awarded a Fulbright Scholarship.

Adam Munoz, a graduate student in Reinhart-King Lab, published a paper named as an "Editor's Choice" in the *Journal of Biomechanical Engineering*, and received a National Science Foundation Graduate Research Fellowship.

Adam Munoz and **Matt Zanotelli**, graduate students in Reinhart-King Lab, published a paper selected as a feature article: "Regulation of ATP utilization during metastatic cell migration by collagen architecture," *Molecular Biology of the Cell*, 2018, 29(1)1-9.

ADMISSIONS

UNDERGRADUATE

Admission to the undergraduate program is managed by the Vanderbilt Office of Undergraduate Admissions. Admissions staff are available to answer questions, arrange campus tours, provide additional information about degree programs, and link visitors with appropriate campus offices and members of the university community.

Office of Undergraduate Admissions
Vanderbilt University
2305 West End Avenue
Nashville, TN 37203-1727
Phone: (615) 322-2561 or (800) 288-0432
Website: *admissions.vanderbilt.edu*

Anita Mahadevan-Jansen
Director of Undergraduate Studies
Department of Biomedical Engineering
Office: 308 FEL Center
Email: *anita.mahadevan-jansen@vanderbilt.edu*
Phone: (615) 343-4787
Fax: (615) 343-7919

GRADUATE

To apply for admission to the graduate program in biomedical engineering, you must first meet the general requirements for admission by the Vanderbilt University Graduate School. Application for admission may be made electronically through the Graduate School website at *vanderbilt.edu/gradschool.* The Graduate School Catalog is here: *vanderbilt.edu/catalogs.*

Vanderbilt University Graduate School
117 Alumni Hall
2205 West End Avenue
Nashville, TN 37240 USA
ATTENTION: Biomedical Engineering
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FINANCIAL AID

UNDERGRADUATE

Vanderbilt is committed to enrolling talented, motivated students from diverse backgrounds. About 65 percent of Vanderbilt students receive some type of aid. Our admissions process is need-blind for U.S citizens and eligible non-citizens, which means the ability to pay for a Vanderbilt education is not a factor in the admissions process. All need-based aid packages now include scholarships, grants (gift assistance), and employment opportunities in place of need-based loans. This initiative does not involve income bands or income cutoffs that limit eligibility. More information can be found at *vanderbilt.edu/financialaid.*

GRADUATE

Students wishing to be considered for financial awards administered by the Graduate School should check the appropriate box under "Financial Information" on the online application and make certain that a complete application is received by January 1. Prospective applicants are urged to apply for fellowships or grants from national, international, industrial, or foundation sources. More information can be found at *vanderbilt.edu/gradschool.*

Graduate students in the Department of Biomedical Engineering seeking the Ph.D. degree receive a competitive stipend, tuition waiver, health insurance and reimbursement for some incidental fees. This financial aid can be in the form of a Teaching Assistantship or a Research Assistantship.

- **Graduate Teaching Assistantships:** Financial aid for the academic year to students who assist in supervised teaching of undergraduates
- **Graduate Research Assistantships:** Financial aid for the calendar year to students carrying out thesis or dissertation research with support from a research grant

Teaching or Research Assistantships may be supplemented by a scholarship or fellowship through a competitive process supported by exceptional applicant qualifications. In order to be considered for these service-free awards, an applicant's file must be complete by January 1. The honor fellowships listed below are in addition to a Teaching or Research Assistantship.

- **Harold Stirling Vanderbilt Graduate scholarships:** $6,000/year for up to five years
- **University Graduate Fellowships:** $10,000/year for up to five years
- **Provost's Graduate Fellowships:** $10,000/year for up to five years
- **School of Engineering Fellowships:** $4,000/year for up to four years plus an award of $1,000 for professional development
- **Thomas R. Harris Fellowship:** $4,000/year for one year, honoring the founding chair of the Vanderbilt Department of Biomedical Engineering

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- Advanced laboratory equipment for hands-on student design experiences
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- Distinguished lectures from leading biomedical engineers
- Student travel awards to enable participation in national conferences

Every gift of every amount is greatly appreciated. For more information about making a gift or pledge to the Vanderbilt University Department of Biomedical Engineering, please contact the School of Engineering Development Office by email (*alumniengineering@vanderbilt.edu*) or at 615-322-4934.

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