The BME Transcript

UNIVERSITY OF DELAWARE | BIOMEDICAL ENGINEERING | FALL 2019

GROWING AND MOVING FORWARD:

WE CELEBRATE OUR TENTH ANNIVERSARY

10 YEARS

UNIVERSITY OF DELAWARE
ENGINEERING

RESEARCH & INNOVATION | FACULTY & STUDENT HIGHLIGHTS | ALUMNI

BME.UDEL.EDU

FRIENDS,

This is an exciting time of *growth and movement* for biomedical engineers at the University of Delaware.

We are welcoming two new faculty members. Our graduate program is ranked No. 44 on the U.S. News and World Report's Best Grad Schools 2020, up from No. 50 in the 2019 rankings. We are doing research that matters and educating the next generation of engineers through our innovative teaching methods and community outreach efforts.

Even more exciting is what is to come. We are preparing to celebrate our 10th anniversary in 2020. In the next year, we will move department offices and several laboratories into the University's new Ammon Pinizzotto Biopharmaceutical Innovation Building, consolidating all of our research at the STAR campus, with great neighbors that include physical therapy, Delaware Bioscience Institute, Delaware Rehabilitation Institute and the National Institute for Innovation in Manufacturing Biopharmaceuticals [NIIMBL].

We are also searching for a new chairperson to lead the department into the next decade.

Connect with us on Linkedin and Twitter, and check us out at bme.udel.edu. As president of the Biomedical Engineering Society (BMES), I also hope to see you at the 2019 BMES Annual Meeting in Philadelphia.

Best wishes,

Dawn Elliott

Blue & Gold Distinguished Professor and Chair
University of Delaware Department
of Biomedical Engineering

TELL US WHAT YOU THINK!

TAKE OUR READER SURVEY AT:
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FALL 2019 BME TRANSCRIPT

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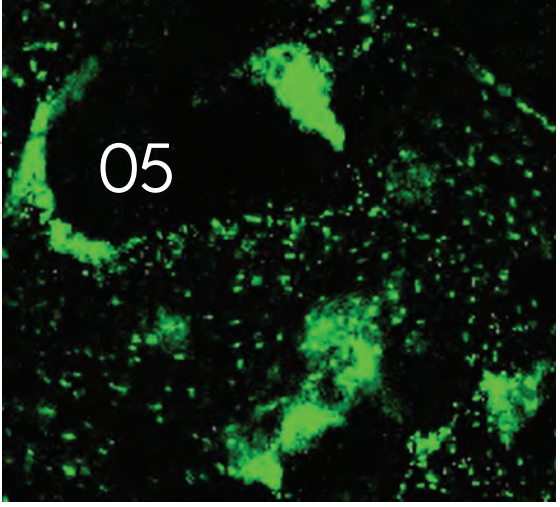
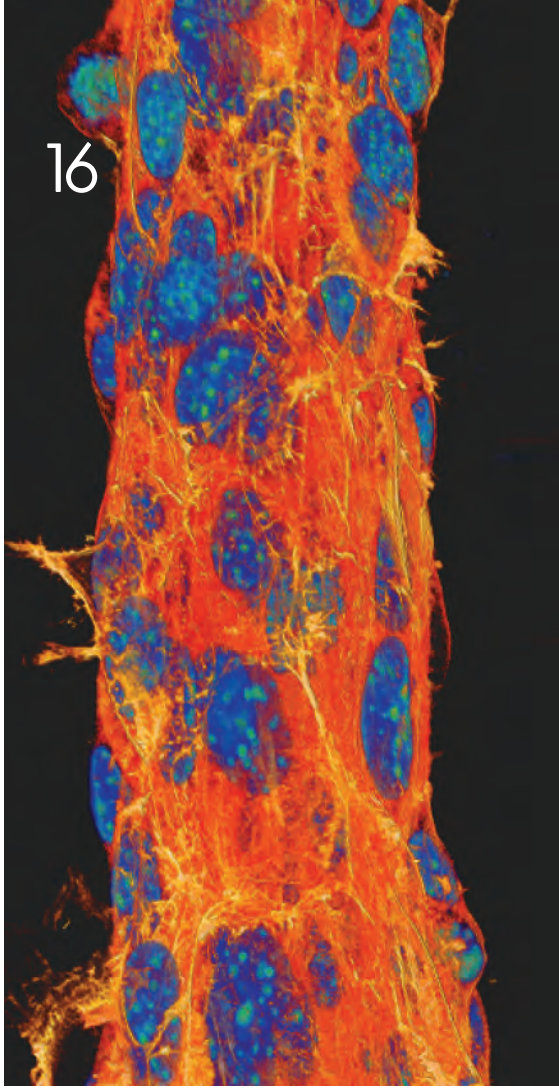




IN THIS ISSUE

GROWING CELL NETWORKS, GROWING TISSUE MODELS

THROUGH TISSUE ENGINEERING AND BOTTOM-UP DEVELOPMENT OF BIOMEDICAL TOOLS, WE ARE BUILDING THE FUTURE OF MEDICINE

Breakthrough in Blood Vessel Engineering

When someone has a deadly disease or sustains a life-threatening injury, a transplant or graft of new tissue may be the best — or only — treatment option. Transplanted organs and skin grafts need blood vessels to bring oxygen-rich blood their way, but for tissue engineers and regenerative medicine experts, making a functional blood vessel network within large tissues in the laboratory has long been a major challenge.

At the University of Delaware, assistant professor Jason Gleghorn and his colleagues have pioneered methods to grow a self-assembling, functional network of blood vessels at a size relevant for human use. The team is the first to make this system work at this scale, and their results were published in the journal *Biomaterials*.

The first author of the paper is Joshua Morgan, a former postdoctoral scholar at UD who is now an assistant professor at the University of California, Riverside. Collaborators also include Jasmine Shirazi, a graduate student in biomedical engineering; Erica Comber, a former undergraduate research assistant who earned an honors degree in biomedical engineering from UD in 2017 and is now pursuing a doctoral degree at Carnegie Mellon University; and Christian Eschenburg, head of R&D at Orthopedic Technology Services GmbH active in Germany, who did research in Gleghorn's lab as part of the Fraunhofer-UD graduate student exchange program.

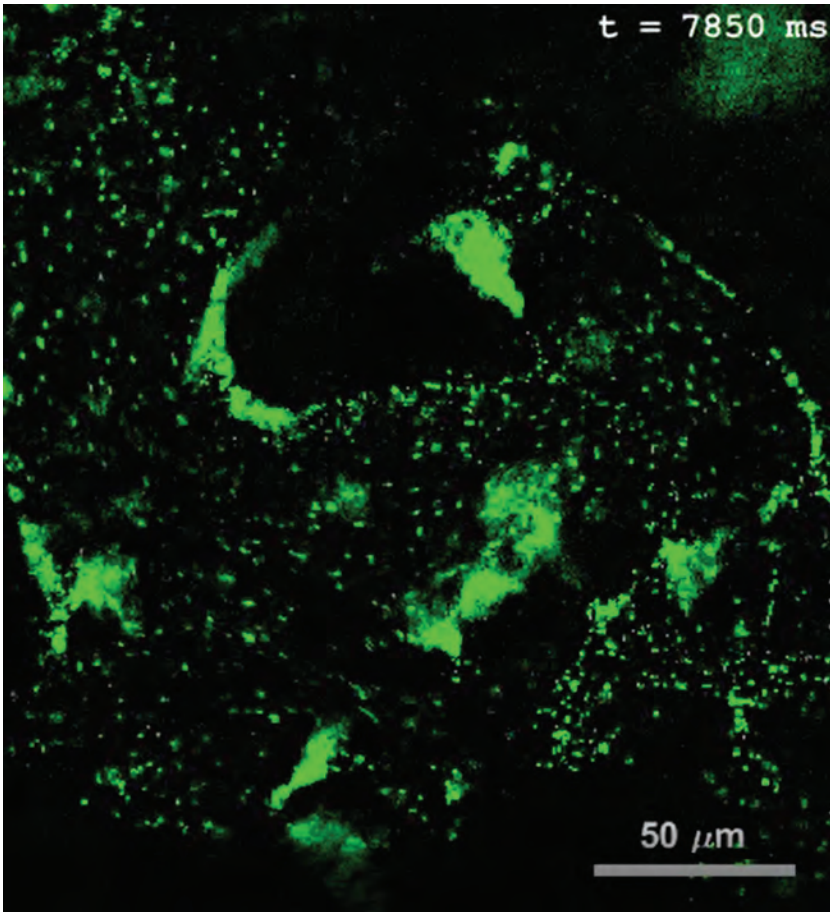
Gleghorn studies how the embryo builds tissues and organs during development with the goal of using this knowledge to define new regenerative medicine strategies. While other groups have made blood vessel networks that span millimeters in size, the UD system works across centimeter scales, necessary for functional tissue replacement. With more development and refinement, Gleghorn's microfluidic system could someday be utilized to grow blood vessels for tissue and organ transplantation into humans.

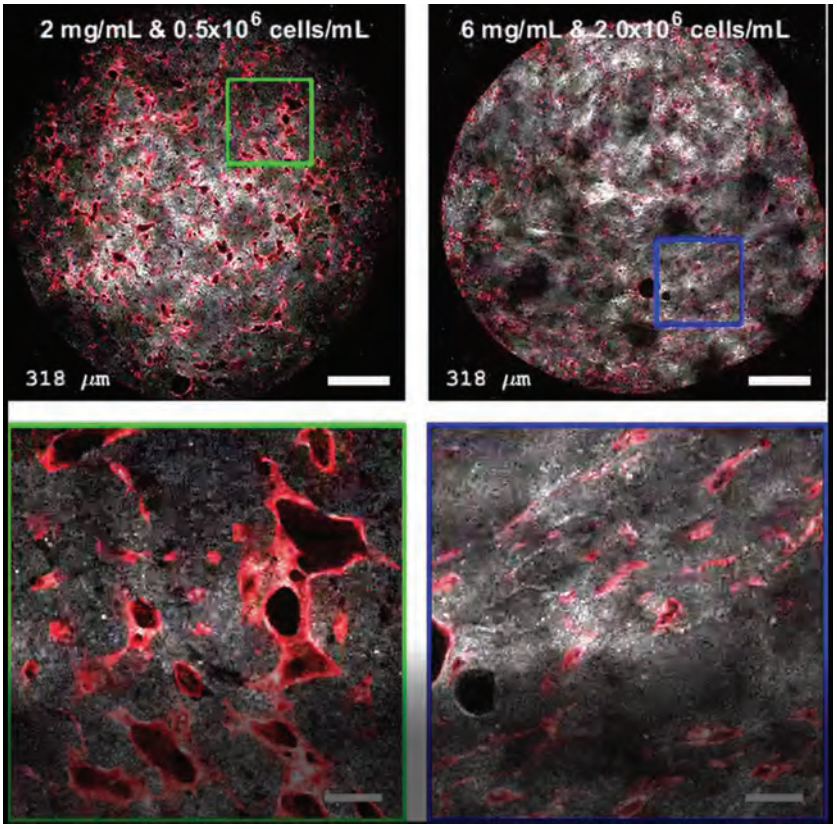
The team embedded human blood vessel cells into a gel made of collagen. The goal was to determine the physical conditions necessary to make the cells grow, multiply and connect with each other so that a network of blood vessels assembled itself.

To do this, Gleghorn's group asked: "What is the fundamental initial starting point of the system that we need, and then can we kick it in the right direction to get it to evolve and build its own architecture similar to the way your body does it during development?" he said.

Using a powerful confocal microscope at the Delaware Biotechnology Institute, the group found that the density, or stiffness, of the collagen gel affected how the cells suspended within it behaved, ultimately affecting the size and connectivity of the vessels. The team also found that by perturbing their system in a specific way, they could affect the size and shape of the vessel networks under assembly.

(continued on page 6)



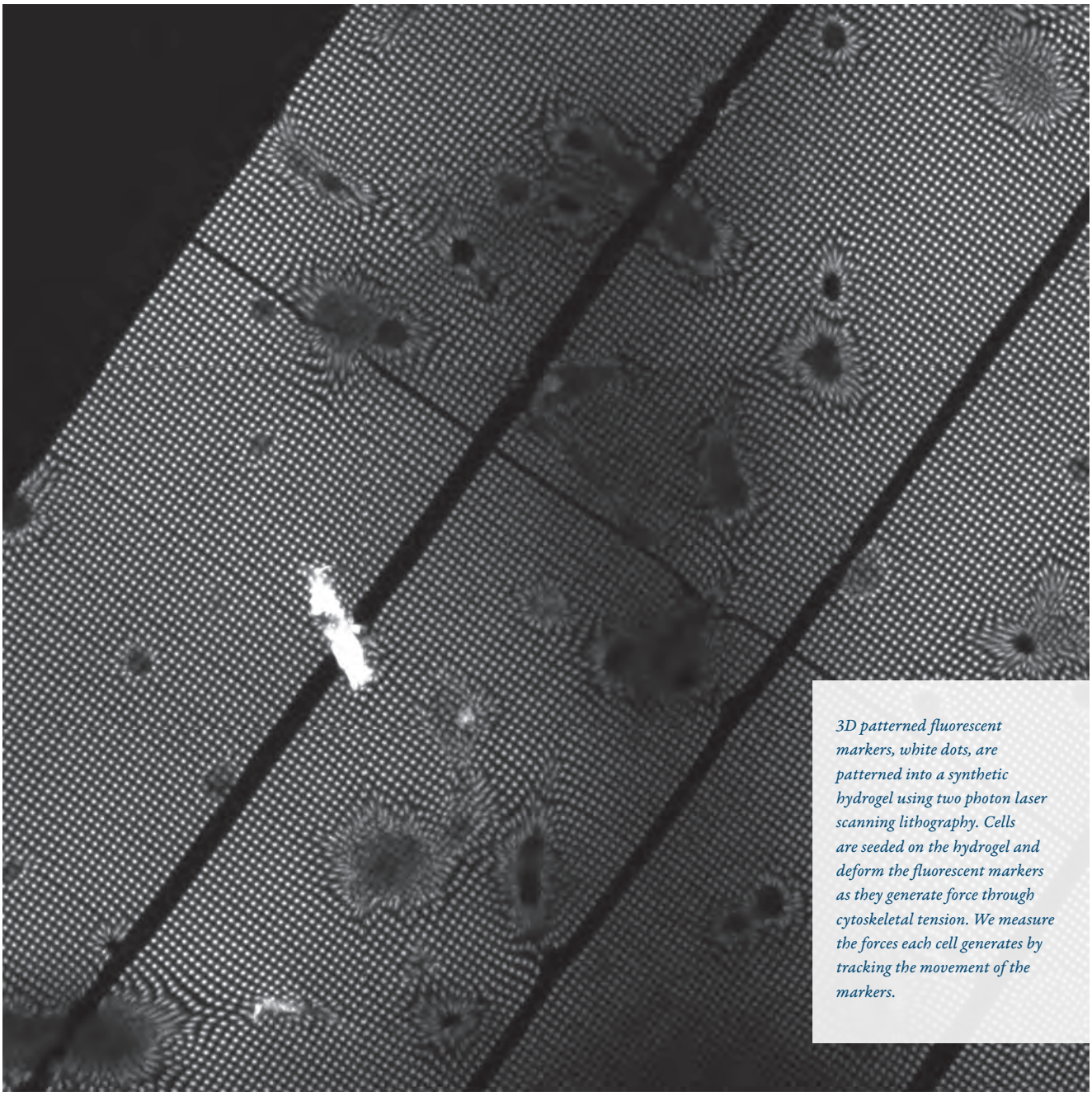


Opposite page: Jason Gleghorn (above) and John Slater (below)

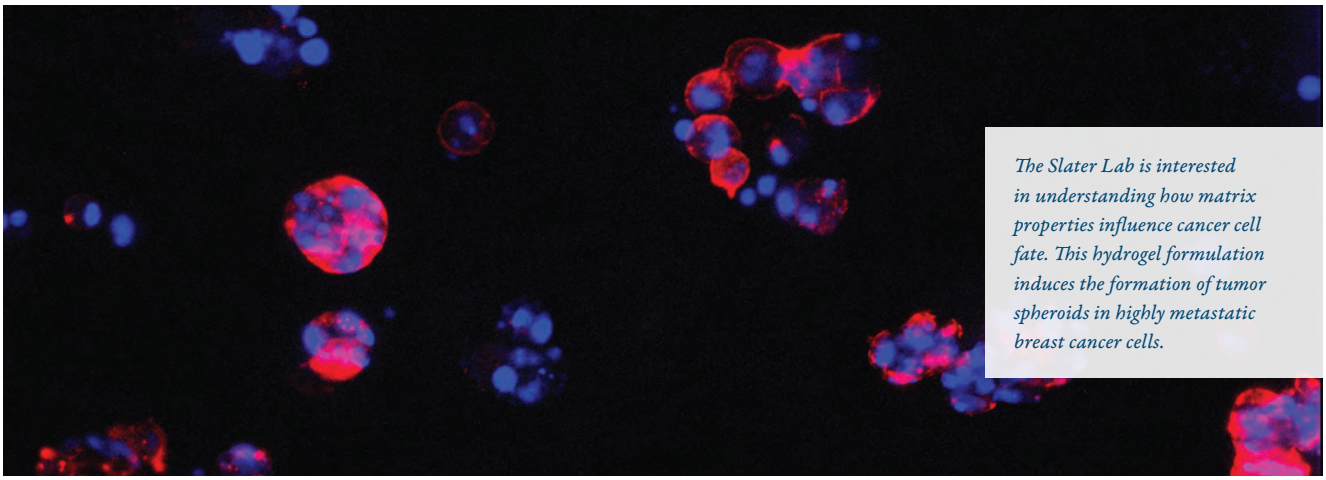
This page : (clockwise from left): Convective flow through a perfusable vascular network.

Collagen gel molded in the shape of UD's letters.

Confocal volumes of two represenative vascular networks.



3D patterned fluorescent markers, white dots, are patterned into a synthetic hydrogel using two photon laser scanning lithography. Cells are seeded on the hydrogel and deform the fluorescent markers as they generate force through cytoskeletal tension. We measure the forces each cell generates by tracking the movement of the markers.



The Slater Lab is interested in understanding how matrix properties influence cancer cell fate. This hydrogel formulation induces the formation of tumor spheroids in highly metastatic breast cancer cells.

"From larger vessels to much smaller microvessels, which are really hard to make, we can now tune the vessel network architecture with the initial starting parameters," said Gleghorn. This means that the new system could have applications from forming larger vessels deep within the body to tiny capillaries, the teeny vessels in your fingertips.

Gleghorn's team also found that their lab-grown blood vessels were perfusable, suggesting that blood could flow through them without leaking out of the vessels into surrounding gel. The vessel networks can also form throughout a variety of shaped gels, meaning that this system could be useful for building blood vessel networks in tissues with complicated shapes, such as meniscus or a large skin graft for burn patients.

New Approaches for Understanding How the Microenvironment Regulates Cell Fate

Assistant professor John Slater studies how cells interact with their surroundings with a particular focus on how physical interactions influence cell behavior. Like many scientists, he uses traction force microscopy to measure the forces generated by cells when interacting with the extracellular matrix that surrounds cells in our bodies.

"An individual cell has actin stress fibers, and when those fibers contract, the cell pulls on the matrix," he said. "The amount it pulls on the matrix—the total force it generates—really influences its behavior." This cell-environment interaction plays a large role in regulating cell fate and allows cells to sense and react to the physical properties of their local environment.

However, traction force microscopy has some drawbacks. The throughput is fairly low, typically only allowing for a handful of cells to be measured in a reasonable amount of time, and the cells that are measured usually have to be destroyed or removed to produce a cell-free reference image for strain measurements and force calculations.

Slater decided to build something better, something nondestructive and suitable for higher-throughput testing. In the journal ACS Applied Materials & Interfaces, Slater and his colleagues, Omar Banda, a PhD student in Biomedical Engineering, and Chandran R Sabanayagam, from the Delaware Biotechnology Institute, recently described how they developed a reference-free traction force microscopy platform.

"We came up with a way that has a built-in zero stress state so you don't have to collect that reference image with the cells gone," he said. To do it, they place fluorescent markers in a highly regular array within the gel using image-guided, two-photon laser scanning lithography.

Slater's system allows for much higher throughput measurements. For example, the team measured the forces generated from 60+ cells in a short amount of time.

The team aims to couple their new system with other assays such as immunofluorescence to understand the role of cell-generated forces in regulating cell fate with a focus on stem cell differentiation, cancer cell behavior, and blood vessel function.

In 2018, Slater was recognized with a Rising Star Award from the Biomedical Engineering Society for this line of research.

In Biomaterials, Slater described the development of a tunable engineered hydrogel platform to control phenotypic cancer cell states to model breast cancer dormancy and reactivation. Slater wanted an approach to generate hydrogels that would allow tight control over their properties. "That way instead of second guessing what the influence was, it would allow us to directly say: This is what's inducing this behavior," he said. The group found that ligand density and enzymatic degradability likely had the most influence on cell fate and hope their findings will aid the development of anti-dormancy therapeutics.

Slater also has ongoing projects to investigate cancer metastasis with a focus on the extravasation process; the process of cancer cells escaping the blood stream to infiltrate new organs. Work in this area has focused on developing a new biofabrication technique termed, image-guided, laser-induced hydrogel degradation technique, to generate 3D biomimetic networks embedded in hydrogels. Recently, he has been working with collaborators, David Mayerich at the University of Houston and Sylvie Lorthois at the Fluid Mechanics Institute of Toulouse in France, to utilize computational modeling to generate biomimetic vasculature that mimics the architecture and flow of native vasculature which has resulted in recent publications in Analytical Methods and Frontiers in Physiology.

SLATER'S TEAM AIMS TO UNDERSTAND THE ROLE OF CELL-GENERATED FORCES IN REGULATING STEM CELL DIFFERENTIATION, CANCER CELL BEHAVIOR, AND BLOOD VESSEL FUNCTION

Dawn Elliott is the inaugural recipient of the Orthopaedic Research Society's Adele L. Boskey, PhD Award.

ON THE MOVE

RESEARCH IN ORTHOPEDICS, BIOMECHANICS AIMS TO HELP PEOPLE STAY MOBILE LONGER

A leader in orthopedics

When the Orthopaedic Research Society wanted to confer its very first Adele L. Boskey, PhD Award, Dawn Elliott, chair of the Department of Biomedical Engineering at the University of Delaware, was the clear choice.

The award recognizes a mid-career member of the society for outstanding and sustained commitment to mentorship and an impactful research program.

"Dr. Elliott exemplifies the traits Adele inspired us to achieve, including integrity, being a strong role model for mentees, and inclusiveness in research, and she is clearly very deserving of this honor," said Nancy Pleshko, professor of bioengineering at Temple University. "Dr. Elliott has been an exemplary mentor to her students, and has been committed through outreach and education to inspire women to join and be successful in both engineering and orthopaedics. Through her leadership, including as Department Chair at University of Delaware, and as current president of the Biomedical Engineering Society, she has gone above and beyond expectations to create educational opportunities and a diverse intellectual community."

Elliott is a distinguished researcher, leader and mentor. After 12 years on the faculty in orthopedic surgery and bioengineering at the University of Pennsylvania, she joined UD in 2011 as the founding chair and sole primary faculty member in biomedical engineering.. The program achieved departmental status and received national accreditation four years later and has already had tremendous research and discovery impact on health and disease, noted Elliott. "Moreover, we are educating the next generation of biomedical engineers who will go on the make the world a healthy place and improve the quality of people's lives."

Elliott is president of the Biomedical Engineering Society and has held leadership roles in the Orthopaedic Research Society and the Bioengineering Division of ASME.

Elliott maintains a research program in the biomechanics of fibrous tissues such as tendon, meniscus, and invertebral disc, studying injury, aging and restoration. She and colleagues at UD recently developed a new framework for modeling viscoelasticity, deformation and damage tendon. She was recently awarded an NIH R01 grant to use MRI and computational models to measure strains in the spinal discs, which will eventually be applied to diagnose the source of low back pain.

HELPING PEOPLE AVOID HIP PAIN

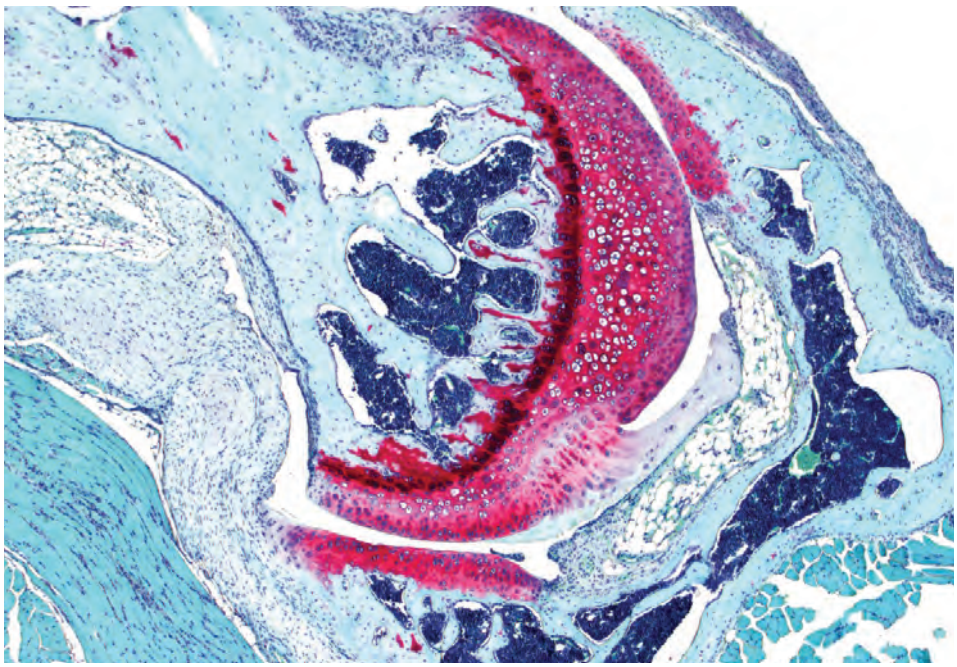
ASSISTANT PROFESSOR MEGAN KILLIAN RECEIVED THE 2018 EARLY CAREER AWARD FROM THE JOURNAL OF ORTHOPAEDIC RESEARCH.

Killian's award-winning research centers on the study of a hip deformity called acetabular dysplasia, a commonly congenital disorder in which the hip socket isn't deep enough to fit the top of the thigh bone. Killian and her colleagues including Ph.D. students (Ryan Locke, BS BME '15), MD students and collaborators from Washington University, and the University of Utah, developed a new model to study how structural and functional changes in the hip during adolescence may affect the development of osteoarthritis.

Acetabular dysplasia can damage hip cartilage and accelerate the onset of osteoarthritis even in young people. Hip dysplasia can also affect dancers and single-sport athletes, increasing their odds of hip pain early in life. An increasing number of Americans under age 50 are developing osteoarthritis of the hip, leading to aches and pains, restricted movement, and impaired quality of life.

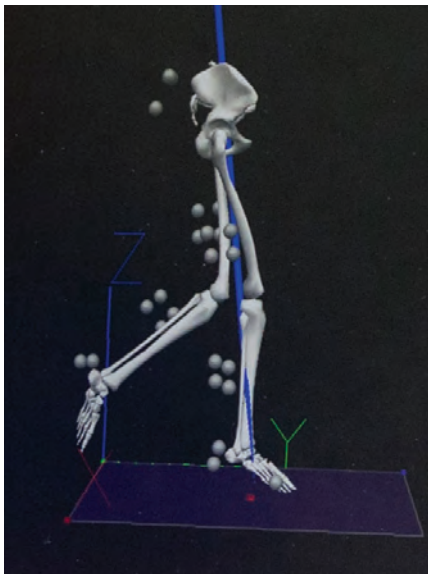
While her work on acetabular dysplasia earned Killian the 2018 Early Career Award from the Journal of Orthopaedic Research, she studies more than the hip joint. Under a grant from the National Institutes of Health, Killian is doing research on muscle activity during the maturation and healing of the rotator cuff, the group of muscles and tissues that helps to keep the shoulder joint in place. Through a new grant from the UD Research Foundation, Killian will also collaborate with materials science and engineering professors April Kloxin and Kristi Kiick to improve tendon healing using designer biomaterials.

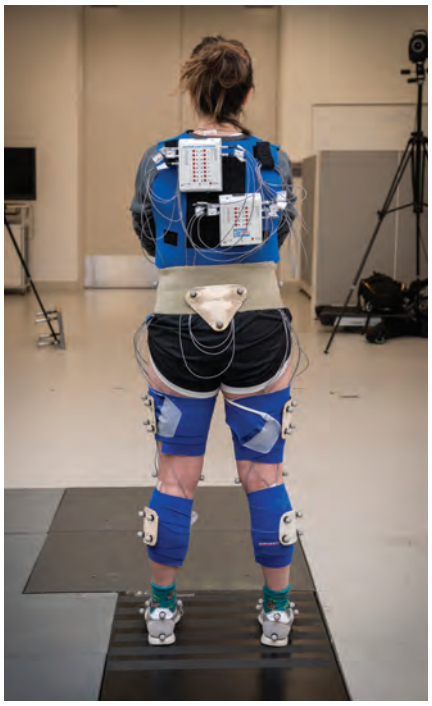
For Killian, the study of joints, muscles, and tendons is a passion she can trace back to her own adolescent years, when her father suffered a back injury. She tagged along with him to physical therapy appointments and befriended the physical therapists, who helped her understand proper running form. This knowledge benefited her through her teenage years and beyond as a three-sport collegiate athlete in cross country, track and Nordic skiing. She still enjoys running in her spare time.



Above, a 3D-printed model of a hip.

Right, a microscopic view of hip tissue.





Megan Leibowitz, a doctoral student in physical therapy, demonstrates motion capture technology used to study how people walk.

REHABILITATING KNEES

A TEAR OF THE ANTERIOR CRUCIATE LIGAMENT IN A KNEE ISN'T JUST PAINFUL IN THE MOMENT — THE INJURY ALSO INCREASES A PATIENT'S RISK OF DEVELOPING OSTEOARTHRITIS LATER.

A research team led by Tom Buchanan, the George W. Laird Professor of Mechanical Engineering, professor of biomedical engineering, and Director of the Delaware Rehabilitation Institute, is teasing out what exactly happens to cartilage as a result of anterior cruciate ligament (ACL) injuries. The team hopes that this insight can be utilized in the development of improved osteoarthritis prevention strategies.

The team, which includes engineering and health sciences students, uses magnetic resonance imaging (MRI) finite element models, gait analysis and biochemical analysis to study ACL injuries and determine which stresses on cartilage may be indicative of osteoarthritis. They collaborate with UD's top-ranked Department of Physical Therapy to collect data from patients and understand the clinical aspects of the injuries they study. "Based on what we identify, maybe physical therapists could treat patients differently," said Buchanan.

The results of one recent paper, published in the Journal of Orthopaedic Research, were surprising. The team studied knee gait variables, muscle co-contraction and knee joint loading in young people with a history of ACL trouble. They found that high muscle co-contraction does not always result in high knee joint loading, thought to be associated with arthritis.

"This suggests that arthritis isn't just caused by really high forces, but can also be caused by too low forces on the joint," said Buchanan. The ideal range of forces may in fact be a very narrow window.

Laura Sturgill, a biomedical engineering undergraduate in the class of 2019, joined Buchanan's lab as a research assistant in 2018 because she wanted more experience studying the mechanical aspects of biomedical engineering. "These applications of statics and dynamics are especially interesting," she said.

Buchanan is also the program coordinator for Delaware's Center for Translational Research ACCEL Program to support and expand clinical and translational research in the state. In October 2018, officials announced that UD and four other institutions will receive $25 million over five years from the National Institutes of Health and the state of Delaware to continue these research programs for improved patient care and public health.

"Engineers play an important role in the expansion of health-related research at UD and beyond," said Buchanan.

UNDERSTANDING HOW CARTILAGE REALLY WORKS

Osteoarthritis affects more than 30 million Americans, and this joint disease is much more common today than it was before the Industrial Revolution.

Associate professor Christopher Price wants to figure out why. He aims to develop a better understanding of cartilage, with the goal of developing treatments to prevent or delay the progression of cartilage breakdown and possibly facilitate the repair and regeneration of damaged joints.

"We are interested in understanding how the cartilage performs fundamental behaviors: load support, low friction, low wear and longevity. "We then need to understand how cartilage responds to different types of perturbations, whether those are regular daily activities or things like injury, and then ultimately understand how that leads to osteoarthritis."

Price and David Burris, an associate professor of mechanical engineering, have developed a novel cartilage explant testing configuration that allows for tribological exploration of these important questions. In typical testing platforms, cartilage moves at speeds slower than typical human movement, and the tissue is dried. That's a problem because the water in cartilage supports much of its load.

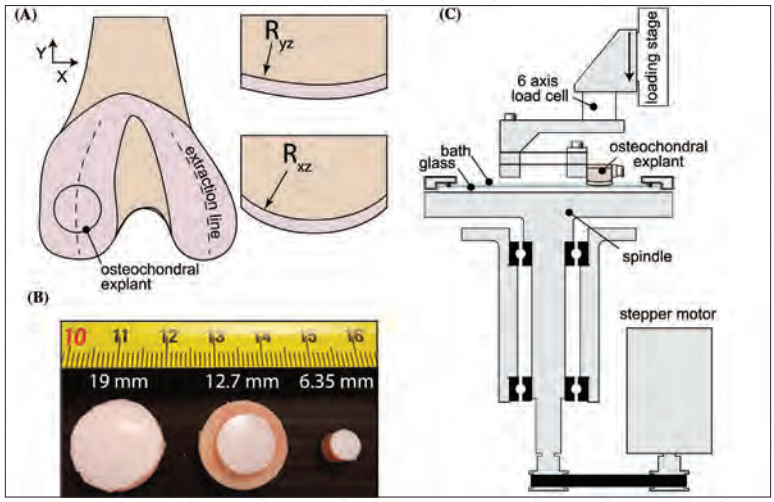
Price and Burris use a tribometer to study lubrication and friction in cartilage samples. They slide or spin the cartilage and record the forces and friction that are generated.

Former doctoral student Axel Moore, now a postdoctoral associate at Imperial College London, has also been instrumental in this work.

Their findings reveal that sliding movements allow cartilage to recover its form and function. "This leads us to the thought that movement might be absolutely necessary to cartilage health," said Price. This could explain why sedentary people might have a higher risk of osteoarthritis than people who are moderately active. The team's research also suggests that short, frequent bouts of exercise might be more beneficial than longer periods.

Next, the group aims to determine how these movements influence the biology of cartilage. They are also studying how cartilage injury affects outcomes and studying how lubricants such as synovial fluid or hyaluronic acid protect cartilage during sliding.

PRICE LAB USES TRIBOLOGY TO UNCOVER MECHANISMS BEHIND OSTEOARTHRITIS



A. Samples were extracted along the central region of bovine femoral condyles
B. Three different sample diameters were used
C. Schematic of the rotary pin-ondisc tribometer used to assess contributions from hydrodynamic factors to tribological rehydration

TEACHING AND

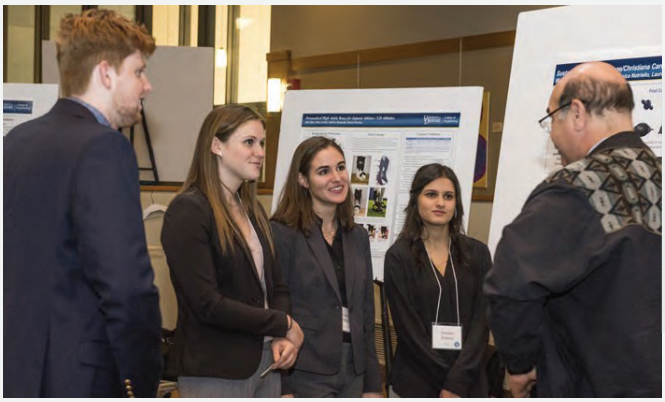
STUDENTS LEARN FROM A PURPOSEFUL MIX OF CLASSROOM EXPERIENCES, INDUSTRY INTERACTIONS AND COMMUNITY ENGAGEMENT

PUTTING IT ALL TOGETHER

From theory to application, fourth-year engineering students at the University of Delaware recently tapped into their knowledge to create products and solutions for clinical and industry sponsors.

For the Senior Engineering Design program, 228 students from four engineering majors (mechanical engineering, biomedical engineering, electrical engineering and environmental engineering) were split into 44 teams to solve problems for 34 sponsors, companies such as Air Liquide, ILC Dover, Xergy, Christiana Care and more. The teams were guided by 13 faculty members, and their projects were judged by 56 evaluators, including professors and industry experts, at the Senior Engineering Design Celebration last December 12, 2018 in UD's Clayton Hall.

Senior Engineering Design asks UD engineering students to synthesize their educational experience to tackle a problem under real business conditions, such as budgetary and time constraints. This experience prepares students for the types of challenges they might encounter in their first jobs and gives them fodder for job interview questions.



A Biomedical Engineering Senior Design Team of (L-to-R) Michael Barboun, Laurel Schappell, Jess Natriello, and Shalaka Sharma share their semester-long design insights with Dr. Hisham Sherif after completing the continuous suction drainage project in collaboration with Dr. David Zabel (not pictured).

OUTREACH

ENGINEERING DISCOVERY DAY

Women are underrepresented in engineering nationally, receiving 21.3 percent of all engineering bachelor's degrees in 2017, according to the American Society for Engineering Education.

At the University of Delaware, a sorority of women in engineering and technical sciences is doing its part to change that. On Nov. 10, 2018, the Alpha Omega Epsilon engineering sorority's Nu chapter hosted a discovery day for young women from area high schools.

The goal of the day? Inform female high school students about engineering and computer science, show them opportunities in these fields and highlight the rise of women in STEM careers.

Fifty students from 26 high schools attended the event. They learned about engineering from several faculty members, including Sarah Rooney, assistant professor of biomedical engineering. They also participated in a campus tour, enjoyed a lunch and question-and-answer session with members of Alpha Omega Epsilon and did a hands-on activity, Scrappy Circuits, which teaches circuitry fundamentals using common materials.

A UD engineering student, helps high school students build circuits during Engineering Discovery Day.

"One of my favorite parts of the day was the hands-on activity," said Rebecca Clements, a sophomore honors biomedical engineering student, the academic and scholarship chair of the Nu chapter of Alpha Omega Epsilon, and the lead organizer of the event. "I was a little nervous about it, but all of the girls really loved it and successfully built their circuits so that they could light an LED. I thought it was great that they were all so enthusiastic and willing to problem solve and try new things."

Clements knows how impactful this early exposure to engineering concepts can be.

"I went to a lot of events like this in high school, and they really benefited me and helped me decide to pursue engineering," said Clements.

HensWEAR

Interdisciplinary team seeks to create smart wearables for athletics and rehabilitation

The University of Delaware HensWEAR team is building on the University's national prominence in rehabilitation, materials science, physical therapy, and fashion and apparel studies to establish a core group of researchers and partners to engineer smart wearables for athletics and rehabilitation and create innovative functional garments and related materials to enhance mobility.

Mobility is a key determinant of quality of life throughout the human lifespan, ranging from early childhood development and learning to healthy physical activity and peak sports performance to maintaining independence into advanced age.

The team, which includes biomedical engineering faculty members Jill Higginson and Fabrizio Sergi, is employing state-of-the-art methods of materials/fabrics processing, fabrication, functionalization and testing, with applications ranging from improving mobility, facilitating recovery and improving/monitoring performance.

One of the smart garment prototypes developed by the HensWear team. Credits: Steve Buchanan, Cheyenne Smith, Huantian Cao, Fabrizio Sergi

HARNESSING UD'S GROWING NEUROSCIENCE NETWORK

SYMPOSIUM REVEALS POTENTIAL FOR NEW PARTNERSHIPS

The study of neural circuits and networks is on the rise at the University of Delaware, which has increased its research capacity with new faculty and neuroimaging technology in recent years.

To better connect and make the most of this expanding expertise, the University held its first Neuroscience Symposium, an event that drew about 130 faculty, researchers, clinicians and students to the STAR Tower on Feb. 22, 2019.

Two leading authorities in the field spent the day with the gathering — Dr. Walter Koroshetz, director of the National Institute of Neurological Disorders and Stroke (NINDS), which is part of the National Institutes of Health, and Prof. Randolph Nudo, an expert in neuroplasticity and recovery after stroke and University Distinguished Professor and Vice Chair of Research in the Department of Rehabilitation Medicine, and the Marion Merrell Dow Distinguished Professor in Aging at the University of Kansas Medical Center.

In addition to UD, participants included researchers and clinicians from Delaware State University, Nemours/Alfred I. duPont Hospital for Children and Christiana Care Health System.

They shared research highlights, considered cross-disciplinary work and new collaborative projects, and met for discussion in small groups focused on cellular, clinical, behavioral, computational and cognitive neuroscience. They looked at opportunities for seminars and workshops, took stock of available core facilities and explored the potential development of a doctoral program and of a new neuroscience institute at UD.

Fabrizio Sergi, assistant professor of Biomedical Engineering, presents his research that combines robotics with neuroimaging to study the neural control of movements.

NIH DIRECTOR COLLINS VISITS UD'S 'VIBRANT RESEARCH COMMUNITY'

Dr. Francis Collins, director of the National Institutes of Health, visited the University of Delaware for the first time on March 1, 2019.

The NIH has invested hundreds of millions of dollars in UD research over the years, including $34 million in fiscal year 2018 alone — making it the single largest sponsor of UD research during the past year.

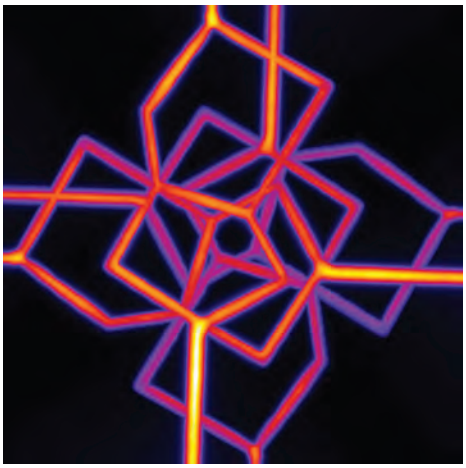
During his visit, Collins connected with those on the front lines of research, toured some of the new and expanding facilities in UD's research enterprise, talked to University students about his work and theirs, and shared a breakfast meeting with President Dennis Assanis and some of Delaware's top elected officials — including U.S. Sens. Tom Carper and Chris Coons and Gov. John Carney.

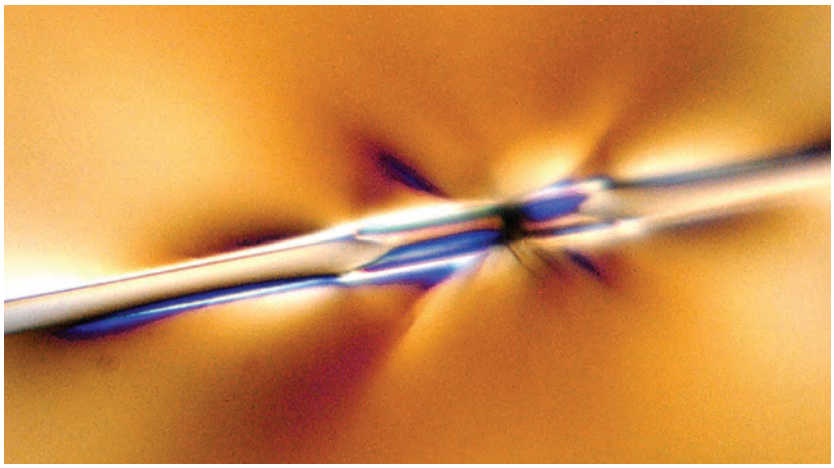
Asked for his top three priorities for NIH now, Collins said he could name 29 or more — then settled on these: cancer, vaccines and opioid addiction.

On cancer, he pointed to exciting advances in immunotherapy as scientists work to activate patients' own immune systems in the battle. He said he knows dozens of dramatic stories of recovery, but also many more of those who do not recover. There is much work to do.

In a tour of labs on the STAR Campus and the Center for Biomedical and Brain Imaging (CBBI), Collins saw NIH support in action. At the CBBI, Director Keith Schneider showed Collins UD's two research-dedicated functional magnetic resonance imaging (fMRI) instruments, so named because they provide images of real-time function, showing researchers exactly where neurons are most active at any given time, in a safe, non-invasive way. While in CBBI, they also heard from biomedical engineering faculty and students working on NIH-funded research projects, including Curtis Johnson, an assistant professor of biomedical engineering who does magnetic resonance elastography, and graduate student Andria Farrens, who works with fMRI-compatible robots.

Several researchers, talked about their work during NIH Director Francis Collins' tour. Among those present were (left to right): National Institute for Innovation in Manufacturing Biopharmaceuticals (NIIMBL) Director Kelvin Lee, U.S. Sen. Chris Coons, Collins, UD Prof. Curtis Johnson, Eleni Assanis and UD President Dennis Assanis.





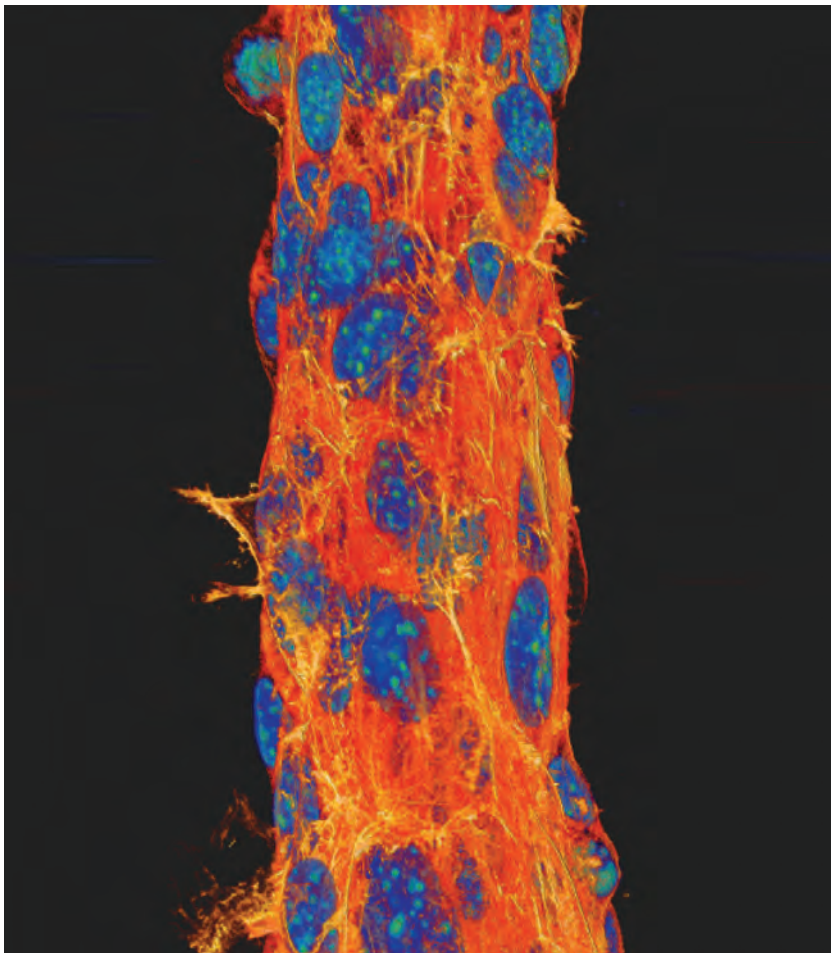
ART IN SCIENCE

Art and science are not opposing forces. Scientific research can produce beautiful art, from an up-close look at tiny green mold spores to a numerical simulation of a meandering river and more.

University of Delaware faculty and students are showcasing the beauty and impact of cutting-edge research across engineering, biological sciences, chemistry, art preservation and more through Art in Science, an annual event sponsored by the National Science Foundation. This year's exhibit debuted on May 3 at the Blue Ball Barn at Delaware's Alapocas Run State Park.

Art in Science caught the attention of NIH director Francis Collins, who featured an image from Art in Science on his blog in 2018.

The founder and director of Art in Science is John Slater, assistant professor of biomedical engineering. He is assisted by several Biomedical Engineering students each year.

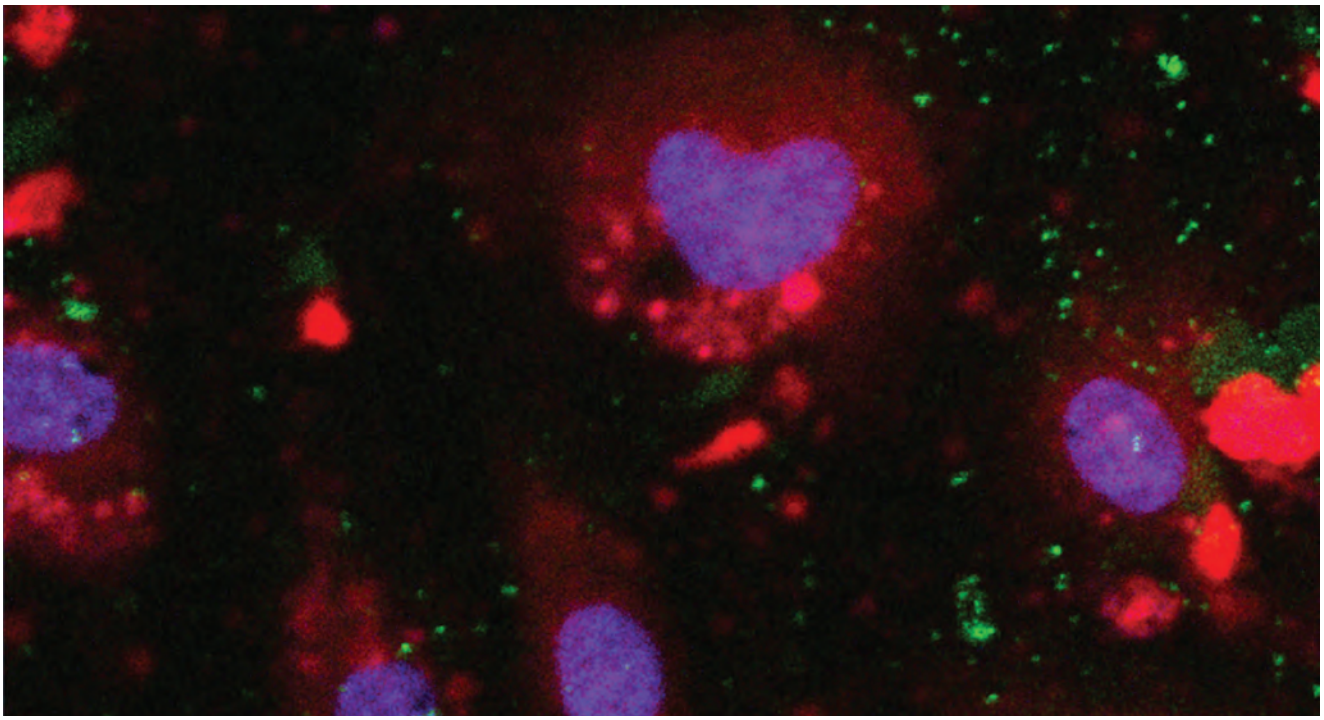


Clockwise from left:

Flow Flower, *Structured Illumination Microscopy by Keely Keller, Biomedical Engineering*

Debond!!, *Optical microscopy, by Brandon Chen, Materials Science and Engineering*

Microfiber Guided Cell Migration, *Confocal Microscopy, by Shuang Liu, Materials Science and Engineering*



Top:

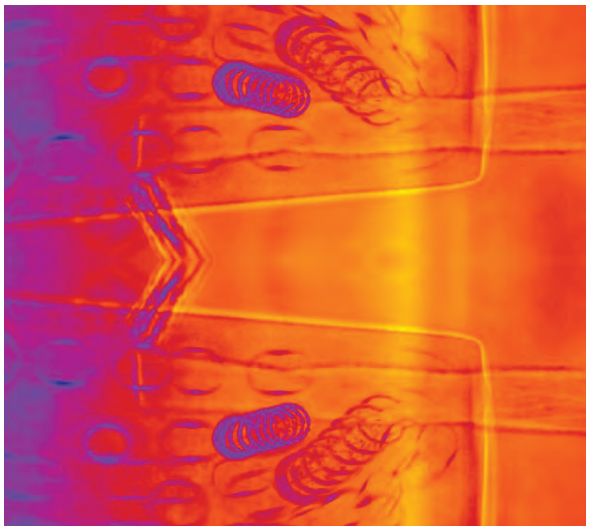
Valentine's day in science!!!, *Two-photon microscopy, by Zeinab Fereshteh, Biomedical Engineering*

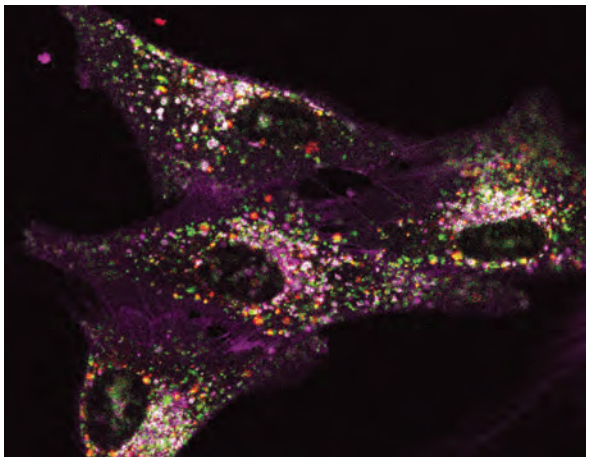
Clockwise from middle :

Cell Paths, *Brightfield microscopy, by Keely Keller, Biomedical Engineering*

Neonatal Mouse Prostate, *Immunofluorescent Microscopy, by Elizabeth Marcin, Biomedical Engineering*

Confetti Cells by Confocal, *Confocal Microscopy, by Jilian Melamed, Biomedical Engineering*








STUDENTS, ALUMNI NAMED NSF GRADUATE RESEARCH FELLOWS

FELLOWSHIP FOR FUTURE LEADERS RECOGNIZES INGENUITY OF UD'S GRADUATES

Photographed left to right: Kelley Marie Kempski, Laurel Schappell, Isabel Navarro, Erica Comber

The NSF Graduate Research Fellowship Program (GRFP) recently awarded fellowships and honorable mentions to multiple biomedical engineering students and alumni from the University of Delaware.

This was a fantastic year for UD students competing for the NSF GRFP for research in biomedical engineering. Five students or alumni received the award and four students or alumni received an honorable mention. This places UD BME in the top ten of biomedical engineering programs by number of undergraduate students receiving the award.

The GRFP recognizes and supports outstanding graduate students in NSF-supported science, technology, engineering, and mathematics disciplines who are pursuing research-based master's and doctoral degrees at accredited United States institutions.

From the class of 2019:

Kelley Marie Kempski, is pursuing a doctoral degree in biomedical engineering at Johns Hopkins University, where she will study in the Photoacoustic and Ultrasonic Systems Engineering (PULSE) lab.

At UD, Kempski did research in the laboratory of Jill Higginson, professor of mechanical engineering and biomedical engineering. "Dr. Higginson taught me how to think for myself and how to create new research projects and follow them through start to finish," said Kempski. She was drawn to Higginson's research on stroke rehabilitation, an area she has a personal investment in because of her Aunt Peggy, who lost the ability to walk after suffering a stroke. "Over the past three years, my Aunt Peggy inspired me to analyze gait to improve walking after stroke resulting in four journal publications, ten conference presentations, two REUs (research experiences for undergraduates) and an immense appreciation for the value of research in clinical practice."

Kempski was also inspired by Curtis Johnson, assistant professor of biomedical engineering, who "first exposed me to my love of medical imaging in the classroom and always encouraged me to reach for my dream school," she said.

Isabel Navarro, a Unidel Eugene du Pont Scholar, did research in the laboratories of three faculty members while at UD: Jason Gleghorn, assistant professor of biomedical engineering; Catherine Grimes, assistant professor of chemistry and biochemistry; Karl Booksh, professor of chemistry and biochemistry. "The Gleghorn lab works on cell and tissue scale biomedical engineering projects, the Grimes lab works on chemical biology, the Booksh Lab works on chemical sensors," said Navarro. "I worked every summer and winter session in the lab!"

Navarro also demonstrated her ingenuity during her junior year when she competed in the First Step Grand Challenges competition, and her team won the Innovation Award for creating a "self-feeder" device for a boy with muscular dystrophy in hopes that those like him can gain greater mobility and lessen the reliance on others. For fun, Navarro was also one of the top contributors to UD Cybersecurity's Capture The Flag team.

Navarro is pursuing a doctoral degree in bioengineering from the University of Pennsylvania, where she will study with assistant professor David Issadore.

She graduated from UD in 2019 with a bachelor's degree in chemical engineering.

Laurel Schappell, biomedical engineering, University of Delaware
Schappell is pursuing a doctoral degree in biomedical engineering at UD. Eventually, she plans to attend medical school to pursue an MD degree with the goal of conducting translational biomedical engineering research in a clinical setting.

She found a home in UD's biomedical engineering department. "Through a number of engineering-centered organizations and BME-focused events like the annual Biomedical Engineering Society conference, I have been able to develop as an engineer alongside some of my closest friends, an experience that has been unique to BME", said Schappell.

Schappell joined the laboratory of Jason Gleghorn, assistant professor of biomedical engineering, in her sophomore year. "Research quickly became an escape from the theoretical nature of many of the engineering core courses and I welcomed the opportunity to apply engineering principles to clinical problem," she said. "Dr. Gleghorn's encouragement to pursue a graduate degree along with a leaning toward engineering problem solving over patient care have significantly altered the direction of my future and inspired me to pursue a career focused on biomedical engineering research." Assistant professors Chris Price and Sarah Rooney have also helped Schappell with guidance on how best to achieve her goals.

Schappell also had the opportunity to study abroad in Italy during the winter session of her sophomore year and competed on the club swim team for four years.

Alumni awards:

Erica Comber, biomedical engineering doctoral student at Carnegie Mellon University and UD-BME class of 2017 and **Cedric Whitney**, UD-BME class of 2017 also received awards.

THE FOLLOWING BME STUDENTS AND ALUMNI RECEIVED HONORABLE MENTIONS

CURRENT STUDENTS

Megan Dang
Biomedical Engineering

Rachel O'Sullivan,
Biomedical Engineering

ALUMNI

Margaret Billingsley,
Biomedical Engineering,
University of Pennsylvania

Amanda Studnicki,
Biomedical Engineering,
University of Florida

CARLY PETTIPAW

ENGINEERING SUCCESS ON AND OFF THE TRACK

The second day of the 2018-2019 school year was a great one for Carly Pettipaw, then a senior majoring in biomedical engineering and a Delaware women's track & field athlete. Not only was she assigned the senior design project that she wanted with Terumo Medical Corporation, she was also offered a full-time job with Siemens Healthineers upon graduation.

Pettipaw was attracted to Siemens, a multinational conglomerate worth billions, at job fairs. While the company wasn't interested in younger students her freshman and sophomore years, as a junior she secured a summer internship with Siemens Healthineers at their location just south of Delaware's campus.

Pettipaw was one of just three interns hired for Siemens' Operations Leadership Development Program (OLDP), a full-time, 24-month rotation between sites in Newark, Boston and New Jersey.

"The whole point is that you can get a better idea for the company as a whole if you have three different roles at three different locations. It also increases your networking abilities," Pettipaw said. "I'm going to have three different experiences in two years which is really unique. That's part of the reason why I accepted the job offer."

Healthineers is the healthcare sector for Siemens, where Pettipaw specifically worked within the laboratory diagnostics sector. Her projects focused on a production line that filled containers with fluids that will be used on a system that runs blood tests.

"If something goes wrong, everything stops for the day. If you want to keep producing batches and keep running things you need to make sure you're running efficiently," Pettipaw said. "It taught me how to think on my feet."

While the internship was in the healthcare sector, the experience expanded into mechanical and manufacturing engineering.

On the track, Pettipaw specializes in middle-distance events like the 800-meter run. Too short to be a long-distance jog, and too long to be an all-out sprint, the 800 can often be a grueling and mentally challenging race. That pressure-packed environment is where Pettipaw is at her best.

In May 2019, Delaware earned its first Colonial Athletic Association (CAA) Women's Track and Field Championship since 2014. Pettipaw took 7th in the 400-meter hurdles.

"Stress gives you an adrenaline rush," Pettipaw said. "It's stressful before races and it's stressful in school and balancing it all. I sometimes thrive under stressful situations. When I'm studying for exams, if I'm not stressed, I'm not studying most effectively. The same with track, too. If I don't have that nervous energy before the race I'm not going to run well."

Competing in athletics and studying engineering at Delaware gave the Mt. Laurel, N.J. native the leadership and team-oriented mindset necessary to be successful in the industry.

"The collaboration, I find that really prevalent in my classes here. Engineering is highly group oriented," Pettipaw said. "All the soft skills I had picked up from being on a team, and especially being an upperclassman having more of a voice on the team, being a leader to the underclassmen. In the classroom setting I feel myself leading my group sometimes and helping to get everyone on the same page."

Pettipaw will rotate through Siemens' three east coast sites for the next two years, after which she will have several possibilities, between a permanent position with Siemens to going back to school for a graduate degree. Whatever path she chooses, her experience at Delaware has laid the foundation for her to succeed.

EXCELLENCE IN GRADUATE STUDENT TEACHING AWARD

Peyton Delgorio, a doctoral student in biomedical engineering, was one of four University of Delaware Ph.D. students named as a recipient of the Excellence in Graduate Student Teaching Award.

She said: "As a former student in the 'Medical Imaging Systems' class, transitioning to a teaching role has been a highlight of my graduate career thus far. This opportunity allowed me to expand my role as an academic mentor by helping students build confidence in understanding complex subject topics. We are told as engineers to create the solutions to the problems we are given. I believe that there are two important factors required in developing valuable solutions: (1) identifying what you know and what you still need to learn and (2) utilizing prior knowledge to effectively research information required for developing the best solution. My goal was to help students understand their potential by building their critical thinking skills. I spent extra time with them working through assignments and explaining more difficult concepts. Contributing to the education of aspiring engineers was both rewarding and satisfying. I hope the critical thinking skills gained from tackling challenging problems in the classroom aided the students' development as future engineers."

STUDENT DEGREES & HONORS

Masters Degrees

Danielle Ferguson
Faculty Advisor: Kristi Kiick,
Associate Morgan Stanley

Geoffrey Ming
Faculty Advisor: Megan Killian

PhD Degrees

Michael David
Postdoctoral Researcher at Washington University, Saint Louis
Faculty advisor: Chris Price

John DeLucca
Research Scientist at Gore
Faculty advisor: Dawn Elliott

Andrea Lee
Medical Writer at BGB Group
Faculty advisor: Dawn Elliott

Aalap Verma
Postdoctoral Researcher at
Thomas Jefferson University
Faculty advisor: Tunde Ogunnaike

Aiden Zerdoum
Reseacher at Princeton University
Faculty advisor: Xinqiao Jia

University Fellowship Awards

Doctoral fellowship
Jasmine Shirazi
Ryan Locke

Dissertation fellowship
Keely Keller
Andrea Zonnino

Graduate scholar
Cindy Farino
N'Dea Irvin-Choy

BME Departmental Awards

Best Doctoral Thesis Award
Rachel Riley

Biomedical Engineering
Best Paper Award
Jilian Melamed

Biomedical Engineering
Distinguished Graduate Scholar Award
Keely Keller

Biomedical Engineering
Graduate Teaching Assistant Award
Nicholas Trompeter

Biomedical Engineering
Rising Star Award
Ryan Locke

Outstanding Graduate Student
Service Award
Mackenzie Scully

Outstanding Biomedical Engineering
Outreach Award
Andria Farrens

Undergraduate Departmental Awards

Biomedical Engineering
Chairperson's Award
Stephen Ioele
Kelly Kempski

Biomedical Engineering
Distinguished Junior Award
Isabel Carulli
Jordan Shuff

Biomedical Engineering
Distinguished Sophomore
Award
Violet Ullman
Julianna Wayne

Matthew Maguire Celebration
of Life Memorial Award
Abigail Dela Paz

Biomedical Engineering
Distinguished Senior Award
Rachel O'Sullivan
Jordyn Schrader

WHERE ARE THEY NOW?

SEE HOW UD BME GRADUATES ARE ACHIEVING SUCCESS WITH THEIR DEGREES.

BACHELOR'S ALUMNI

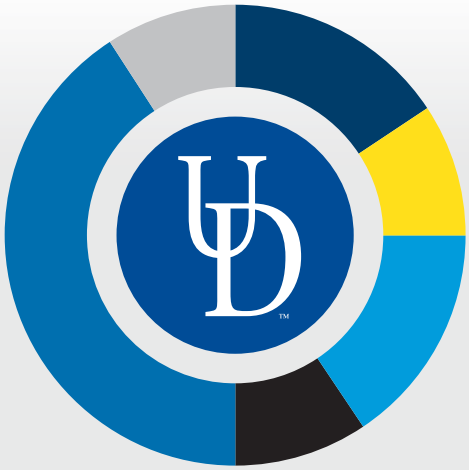
of biomedical engineering graduates are employed or pursuing further education.

$55,000
Median starting salary

TOP EMPLOYERS

Siemens Healthineers
University of Delaware
Suvoda
Terumo Medical Corporation
Agilent Technologies
Eurofins Lancaster Laboratories
Nemours/Alfred I. duPont Hospital for Children
QPS Holdings
Stryker
U.S. Navy
W. L. Gore & Associates
Acell
Air Liquide
Cook Medical
Danico Medical
Globus Medical
Johnson & Johnson
LabWare Global Services
MTF Biologics
Perry Initiative
Smith & Nephew Orthopaedics

Source: University of Delaware Career Outcomes, BME Classes of 2015-2018



PhD ALUMNI

42% Postdoc
8% Interviewing
17% Assistant Professor
8% Cardiothoracic Surgeon
17% Industry Research Scientist
8% Medical Writer

2016-2019

FACULTY ACCOLADES

Top to bottom: Emily Day, Dawn Elliott, Jason Gleghorn

Assistant professor Emily Day was selected by the University's Francis Alison Society to receive the 2018 Gerard J. Mangone Young Scholars Award. The award recognizes promising and accomplished young faculty. The recipient is chosen by fellow faculty members who have received the Francis Alison Award, the University's highest competitive faculty honor. Day studies nanomedicine, gene regulation, photothermal therapy and translational cancer research. She also recently received an NIH R01 award of $1.7M to study multifunctional siRNA/antibody nanocarriers to treat metastatic triple-negative breast cancer. Day was also awarded the 2018 Rita Schaffer Young Investigator Award from the Biomedical Engineering Society.

Dawn Elliott, department chair and Blue and Gold Distinguished Professor of Biomedical Engineering, received the 2019 ORS Adele L. Boskey, PhD Award (see page 8). She also recently received an NIH R01 competing renewal funded to study internal disc deformations using MRI. This project has been continuously funded since 2005. At the Orthopaedic Research Society's 2019 Annual Meeting in Austin, Texas, Elliott was an invited plenary speaker to debate: Dysfunctional Biology Rather than Mechanics is the Primary Cause of Degenerative Disc Disease.

Assistant professor Jason Gleghorn received an NIH NHLBI $1.9M R01 grant award with collaborators at University of Texas Dallas to investigate how mechanical forces spatially pattern cell proliferation and drive airway formation in the developing lung and an NIH NHLBI $2.6M R01 grant award with collaborators at Baylor College of Medicine to study sex-based differences in lung blood vessel formation in late stage lung development to inform the treatment of premature babies. Read more about his research on page 4.

Jill Higginson, a professor of mechanical engineering and biomedical engineering, was inducted into the College of Fellows of the American Institute for Medical and Biological Engineering (AIMBE) in March 2019. Election to the AIMBE College of Fellows is among the highest professional distinctions accorded to a biomedical engineer.

Higginson was selected for contributions to the field of neuromuscular biomechanics of pathological movement, musculoskeletal modeling and simulation, and undergraduate research and education.

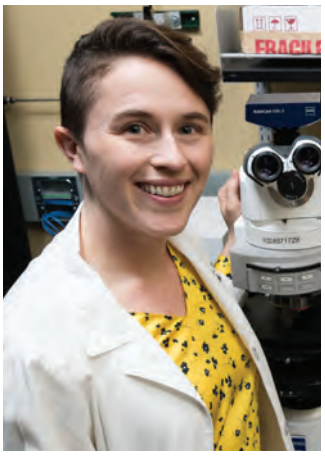
In August 2019, Higginson was named Associate Dean of Graduate and Post Graduate Education for the College of Engineering.

Assistant professor Curtis Johnson received an NIH R01 award of $2.7M in 2019 to measure the in vivo mechanical properties of white matter tracts in the human brain through a novel, integrated technique termed anisotropic magnetic resonance elastography (aMRE). Accurate measurements of white matter mechanical properties will provide an important contrast related to the microstructural health of brain tissue expected to be highly sensitive to disease. This project will validate the aMRE measurement in simulations, phantoms, animals, and humans, and position aMRE for use in the diagnosing and treating neurological conditions.

Johnson received the 2018 Research Summit Award, from the Delaware INBRE Program. He is also the recipient of an NSF award to study mechanical properties of forearm muscles during fine motor tasks using MRE in collaboration with Fabrizio Sergi at UD.

Assistant professor Ashutosh Khandha received a 2018 NSF SBIR Innovation Corps Phase 0 Award. Khandha teaches undergraduate and graduate courses pertaining to medical device design, imaging, instrumentation and biomechanics. He also mentors undergraduate student teams for junior and senior design projects.




Top row: Ashutosh Khandha; John Slater, Jill Higginson
Middle row: Megan Killian, Curtis Johnson
Bottom row: Fabrizio Sergi, Elise Corbin

Assistant professor Megan Killian won the Journal of Orthopaedic Research Early-Career Award. Read more about it on page 9. She also received funding from the University of Delaware Research Foundation Strategic Initiatives to translate designer biomaterials from the laboratories of her COE mentors, Drs. April Kloxin (Chemical Engineering) and Kristi Kiick (Materials Science and Engineering) to a preclinical model of tendon injury. Additionally, Dr. Killian also received pilot funding from the Delaware Center for Translational Research ACCEL Program for this collaborative project with Kloxin and Kiick.

Assistant professor Fabrizio Sergi received two NSF awards this year, one in collaboration with Curtis Johnson at UD to study mechanical properties of forearm muscles during fine motor tasks involving the hand and wrist using MRE, and one in collaboration with Jennifer Semrau, Hyosub Kim, and Jared Medina, to use robotics to study proprioception in post-stroke impairment. Moreover, he recently received a pilot grant to develop a soft robotic garment for assistance to the upper extremity through UD's HensWEAR project. Two papers co-authored by him and his graduate students Robert McGrath and Andrea Zonnino were selected as finalists for the Best Paper Award at RehabWeek 2019 in Toronto.

Assistant professor John Slater was named a 2019 Emerging Leader in Biological Engineering from the Journal of Biological Engineering. He received the 2019 Dean's Award for Excellence in Service and Community Engagement from the University of Delaware College of Engineering and the 2018 NIH Delaware INBRE Research Summit Award. Read more about his research on page 5.

Assistant professor Elise Corbin was awarded the Delaware CTR ACCEL for pilot funding to model and study how sepsis-derived inflammations lead to contractile impairments of human cardiac tissue.

INTRODUCING OUR NEW FACULTY

THE BIOMEDICAL ENGINEERING DEPARTMENT IS DELIGHTED TO ANNOUNCE THE ADDITION OF TWO NEW FACULTY MEMBERS.

Julie Kohn has joined us in fall 2019. Kohn is an avid educator and seeks to incorporate hands-on learning techniques into her lectures. She believes in the importance of developing well-rounded engineers, who can think critically and thrive both independently and on team-based projects. Kohn holds a doctoral degree in biomedical engineering from Cornell University. Her research background centers on understanding which factors contribute to cardiovascular disease and how these factors initiate plaque development in the arteries. To answer these questions, Kohn has conducted experiments on the bench top, in mouse models, and by using computer modeling. She was most recently a Fulbright U.S. Scholar in Tanzania, where she examined arterial stiffness in human subjects.

Joshua Cashaback is joining us in spring 2020 as a tenure-track assistant professor. His research interests include neuromechanics, sensorimotor control and learning, biomechanics, optimal feedback control, learning algorithms, Bayesian statistics, multi-objective optimization, limb dynamics, and muscle modelling. He holds a doctoral degree in biomechanics from McMaster University in Ontario, Canada. He was most recently a post-doctoral fellow in the Human Performance Lab at the University of Calgary, where he studied a neuromechanical model to evaluate muscle contributions to ankle stiffness and the sensorimotor system's use of robust control to deal with environmental load uncertainty.

BME ADVISORY COUNCIL

Helen C. Stimson (chair)
Delaware Bioscience Assoc., President
Alumni Parent

Michael J. Axe, M.D.
First State Orthopedics, Founding Partner
Physical Therapy, Adjunct professor

Devon Wheeler Bond
B.S. Biomedical Engineering '14
CryoLife, Process Engineer

Anthony Coston, Ph.D.
B.S. Electrical & Computer Engineering
Draper, Head of Medical Devices

Alan Eberhardt, Ph.D.
B.S. Civil Engineering
University of Alabama, Birmingham,
Professor BME

John V. Flynn, Jr, PhD
B.S. ChemE '64
Deloitte Consulting (retired)

Vicky Funanage, PhD
Ph.D. in Biological Sciences '81
Nemours Children's Health System,
Operational VP, Research

John T. Kramer
B.S. ChemE '82
W.L. Gore & Assoc (retired)

Sandra Lewisch, PhD
Siemens Healthineers, Sr. Director R&D

Michele S. Marcolongo, PhD
B.S. MechE '86
Drexel Material Science & Engr, Chair

Linda J Myrick, PhD
B.S. ChemE, Alumni Assoc Pres
Arkema, Gen Mgr Americas,
Oxygenates & Derivatives

Collin Patterson
B.S. Biomedical Engineering '16
Globus, Project Development

Brian Pryor, PhD
Litecure, Co-Founder & CEO

Bruce Robertson, PhD
Ph.D. ChemE
H.I.G. Capital, Managing Director

Jae Sly, PhD
Strategic BioPharm Consulting, CEO

James Sonnet, PhD
Ph.D. ChemE
Redwood Innovations, Managing Partner

Judy Sonnet
Center for Leadership & Innovation,
Managing Partner

Elizabeth Soulas
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University of Pennsylvania, Dental &
Bioengineering Student

Scott Waldman, MD, PhD
Thomas Jefferson University,
Pharmacology Dept Chair

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B.S. Business & Ecomics
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