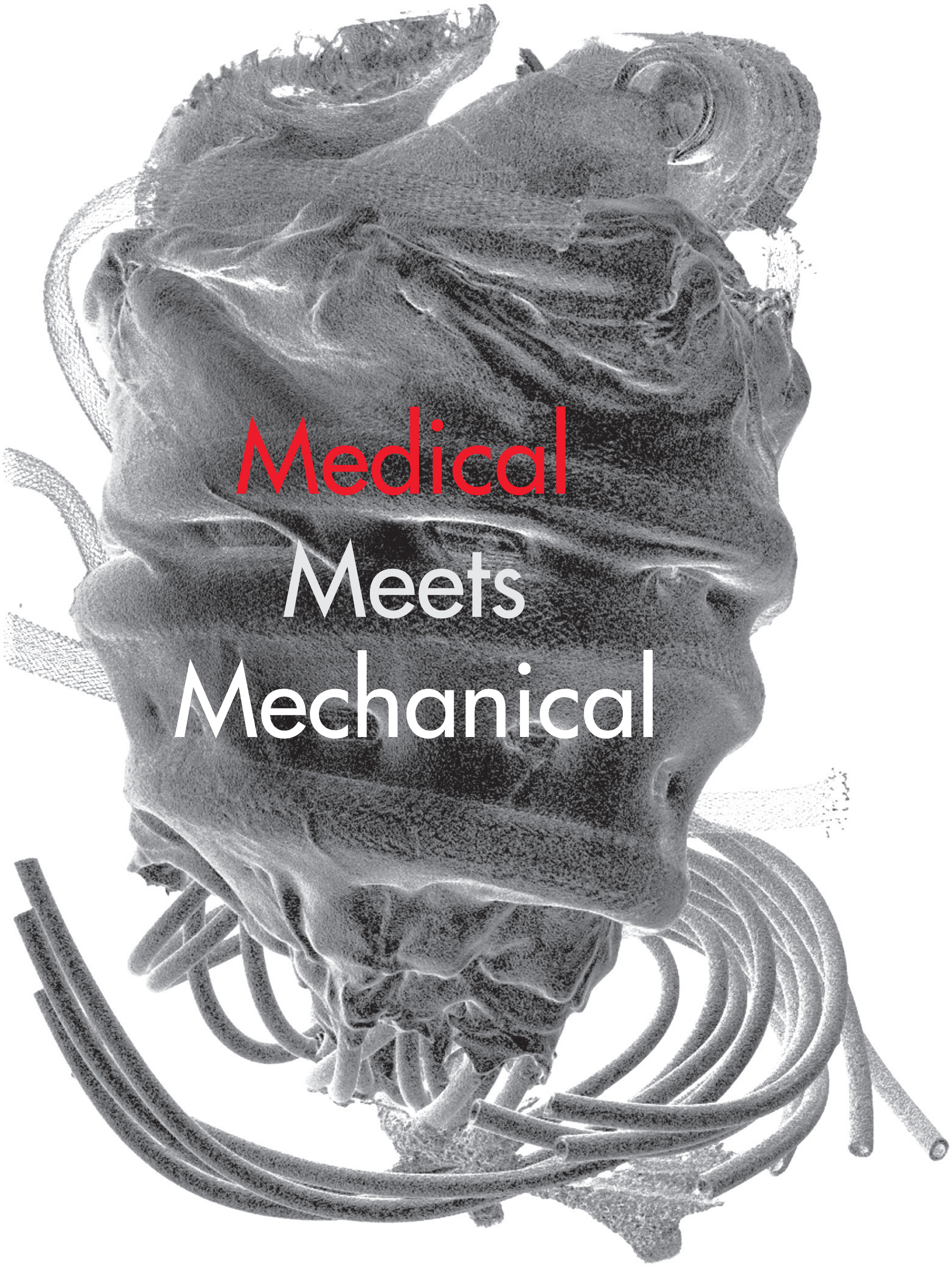
MIT MECHE

# MechEConnects

Winter 2018



# Medical Meets Mechanical

MechEConnects

News from the MIT Department of Mechanical Engineering

Winter 2018 | ► meche.mit.edu

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A team of students from the class 2.009, Product Engineering Processes, presents their low-cost defibrillation device that could fit in a backpack and deliver heart-starting shocks using just the power of a smartphone battery. Credit: 2.009 Photo Staff


Massachusetts Institute of Technology

## About MechE

One of the six founding courses of study at MIT, mechanical engineering embodies the motto "mens et manus" – mind and hand. Disciplinary depth and breadth, together with hands-on discovery and physical realization, characterize our nationally and internationally recognized leadership in research, education, and innovation.

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**Cover:**
A tomography image shows a soft robotic device enveloping a pig heart. Developed by Assistant Professor Ellen Roche, the device mechanically assists the heart in pumping. Credit: Roche et al./*Science Translational Medicine*



MITMECHE

**The research being conducted at MechE is shaping our understanding of the human body and how to treat the effects of trauma, disease, and aging.**

Dear Alumni, Students, Faculty, and Friends,

The human body is made up of numerous intricate mechanical systems. It comprises joints that allow it to move, tubes that carry blood throughout the body, and valves that control the release of digestive enzymes. These parts all work in exquisite synchronicity to keep us alive and healthy.

A large percentage of the faculty and students in MIT's Department of Mechanical Engineering conduct research that relates to the human body and the medical field. This research ranges from the nano to the macro scale. Whether it's using biophotonics to map how neurons interact or developing new methods of genetic engineering, the research being conducted at MechE is shaping our understanding of the human body and how to treat the effects of trauma, disease, and aging.

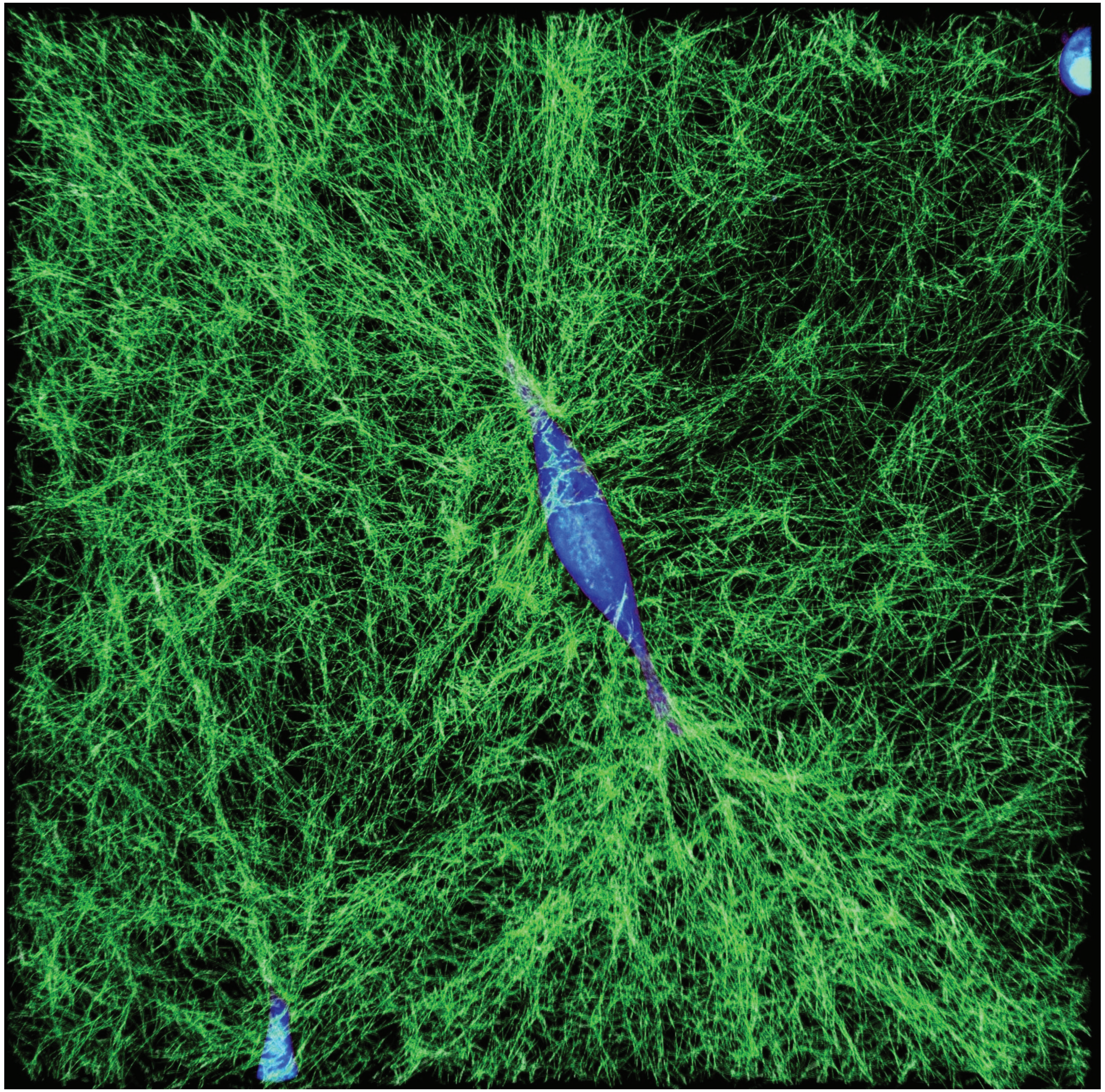
Much of the medical research conducted by our students and faculty is interdisciplinary in nature. In addition to collaborations with colleagues in MIT's Department of Biological Engineering, MIT Medical, MIT's Institute for Medical Engineering & Science, and Harvard Medical School, our researchers regularly cross the Charles River to work with leading surgeons and doctors at Boston's world-renowned hospitals.

In this issue, we hear from the faculty members, students, and alumni who work at the interface of mechanical engineering and medicine. By approaching problems in human health and disease from an engineer's perspective, these members of the MechE community are unlocking the mysteries of the human body and developing new, innovative solutions and treatments in human health.

We hope you enjoy this issue of MechE Connects. As always, thank you for your ongoing support and friendship.

Sincerely,

Gang Chen, Carl Richard Soderberg Professor of Power Engineering and Department Head



A human breast cancer cell (in blue) spreads in a 3D collagen gel network (green). Credit: Ming Guo



# Understanding and Treating Disease

By Mary Beth O'Leary

In 2006, there was a discovery that opened up a new world of possibility for treating diseases. For the first time, researchers created stem cells without using embryos. Adult skin cells were reprogrammed into induced pluripotent stem cells, or iPSCs that could differentiate into specialized cells for use in almost any part of the body – from the liver to the heart or brain, and everywhere in between. Areas of the body damaged by disease could be made healthy again.

But after over a decade of research on iPSCs, the process of creating them is still incredibly inefficient. "We have been puzzled that after 10 years of intense research in that direction, the efficiency of iPSC reprogramming is still only about 0.1%," says Associate Professor Domitilla Del Vecchio. "It's not really at the point that you can use it for clinical purposes."

Del Vecchio and her colleagues are hoping to change that. Currently, researchers develop iPSCs by delivering synthetic DNA to the nucleus of a somatic cell, such as a skin cell. This synthetic DNA produces high levels of select proteins – known as transcription factors – with the aim of "pushing" the somatic cell to reprogram into a stem cell. But overloading a cell with such a high-level of transcription factors leads to a highly inefficient process. "If you have a mechanical system, such as a car or a robotic manipulator, and you give it an arbitrary push, you should not expect that the system will end up exactly in the configuration you want," explains Del Vecchio.

To fix this problem, Del Vecchio and her team are adding accelerators and brakes to the process. Using mathematical analysis, they can demonstrate that with an appropriate balance the pluripotent stem cell state can be reached. With the help of small molecules, the synthetic DNA delivered via a virus can produce tunable levels of transcription factors based on a target configuration. This method – called a synthetic genetic feedback controller – can be used to steer the concentration of transcription factors in the cell to the point at which it can become a stem cell.

The applications of Del Vecchio's work may have far-reaching implications for the way diseases are treated. Researchers could quickly create healthy heart cells for patients with a heart condition or beta-cells for diabetic patients.

> Researchers are developing new and innovative ways to deepen our understanding of disease and unlock new therapies to treat it.

Del Vecchio's eyes light up when discussing the possibilities. "It's clearly high risk," she admits. "But we want to proceed in this direction because if it works, it will be highly impactful for society and hence extremely rewarding for us."

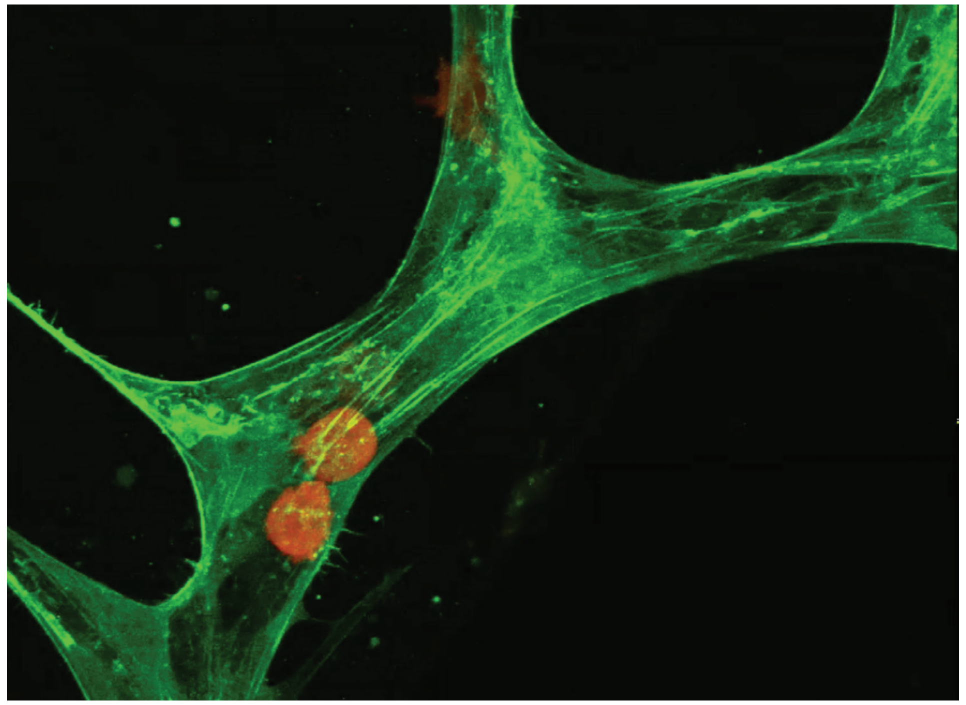
Giving doctors the ability to quickly create stem cells could change the way many diseases are treated. The research Del Vecchio's team is conducting represents just one example of how mechanical engineering researchers across a diverse range of specialties are developing new and innovative ways to deepen our understanding of disease and unlock new therapies to treat it.

## Diagnosing Disease

Understanding disease starts with the cell. Assistant Professor Ming Guo, who serves as the d'Arbeloff Career Development Professor, is interested in decoding the differences between the mechanical properties of a healthy cell and a diseased cell as a diagnostic tool. "Just by looking at a healthy cell compared to a diseased cell, you can tell that they're different mechanically," explains Guo.

Stiffness in particular is a key trait in distinguishing what kind of disease a cell has – for example cancer cells have been shown to be soft while asthma cells are often stiff. Currently, this information is probed by contact-only methods such as atomic force microscopes or optical tweezers, which use either a mechanical tip or a focused laser beam on a patient's tissue to measure cell properties. Guo and his colleagues have now developed a safer, less invasive method of analyzing the mechanics of a cell to help formulate a diagnosis by simply taking a small sample of cells and watching them using a standard optical microscope.

"We came up with the method by simply observing the movement of organelles in the cell," says Guo. The team took videos of cells under a microscope. They tracked the movements of individual organelles or particles within the cell at frequencies of 10 frames per second and higher. Then, by plugging the value of these movements into a generalized form of the Stokes-Einstein equation, they were able to calculate the exact stiffness of a cell.



Using a 3D vascularized network constructed in a microfluidic device, researchers capture the moment of extravasation – when a tumor cell (in red) leaves the blood stream (in green) and becomes metastatic. Credit: Roger Kamm

Del Vecchio's lab uses viruses to deliver synthetic DNA to somatic cells with the aim of turning them into stem cells. Credit: John Freidah


"We found that high frequency fluctuation can help us gauge cell stiffness and understand its mechanics," Guo explains. Understanding these mechanical properties can help doctors diagnose diseases on-the-spot. Guo has begun collaborating with doctors at Massachusetts General Hospital on applying this method to cancer and asthma cells. The hope is that doctors and researchers can test drug efficacy by measuring a cell's mechanics before and after treatment.

## Tracking Disease

While improving diagnostic methods could help catch a disease early, tracking how diseases grow could be key to developing new therapeutic interventions. Roger Kamm, Cecil and Ida Green Distinguished Professor, and his lab use a device that's roughly the size of a quarter to track tumor cells as they leave the vascular network and eventually grow into tumors. These tiny microfluidic devices can help us understand how cancer metastasizes.

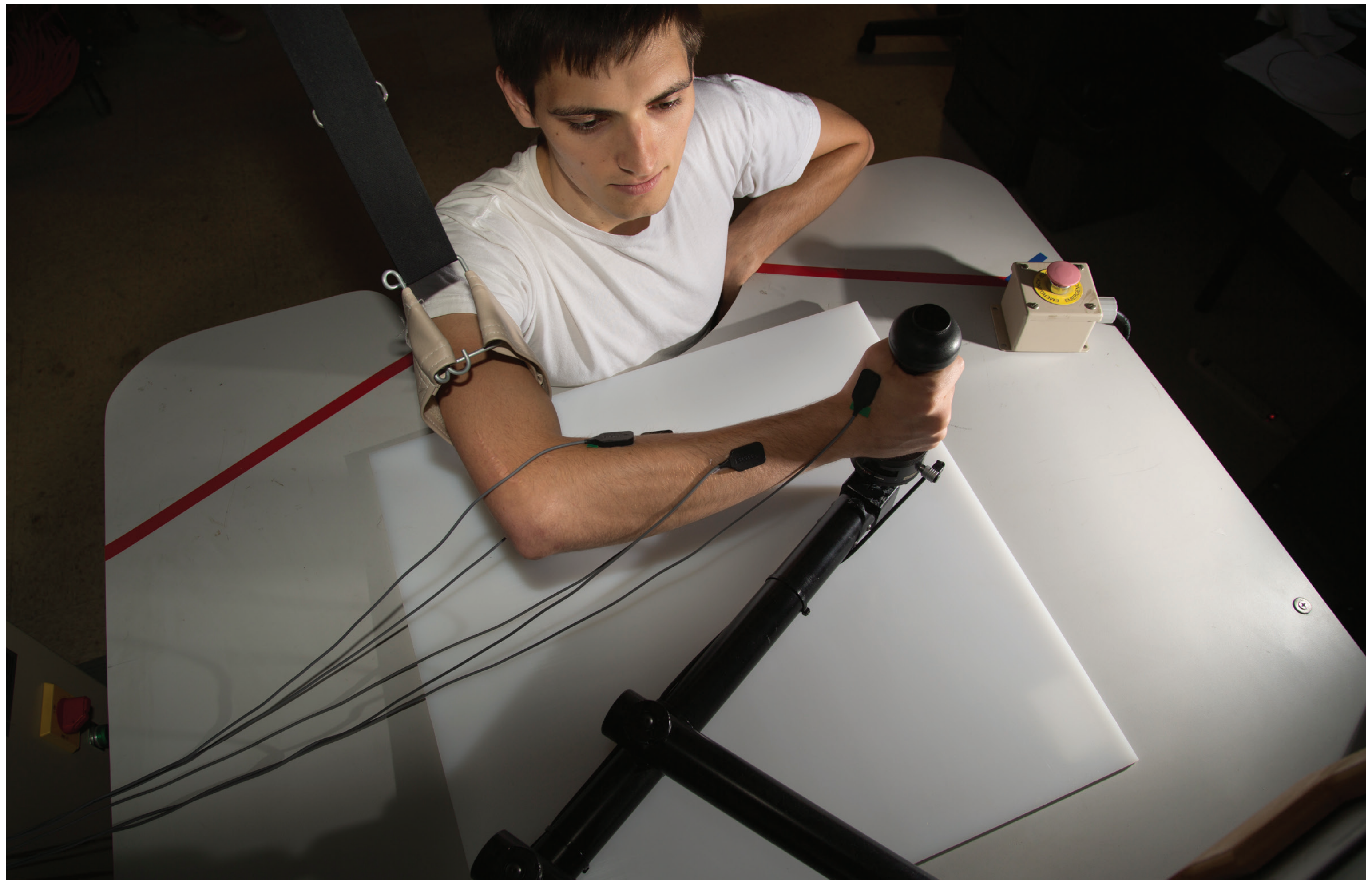
"We've developed a 3D vascularized network in which we can track cancer cells inside a capillary," explains Kamm. "It's about understanding how cell populations interact. We can watch the tumor cells escape from the vessel to invade the surrounding tissue."

The microfluidic device consists of two media channels on either side with 3D hydrogel in the center. The gel is seeded with endothelial cells that form capillaries where the tumor cells are introduced. From there, Kamm and his team use microscopic imaging to watch every single movement the tumor cell makes. From intravasation – when a cancer cell enters the bloodstream – to extravasation – when a tumor cell leaves the blood stream and becomes metastatic – the cell's path is studied with painstaking precision.

"Using microfluidics, we can follow this process over time," explains Kamm. "After the cell enters the metastatic organ, we can see how a single tumor cell starts to multiply over days and how it begins to form a metastatic tumor."

Microfluidic devices allow Kamm to analyze the forces that inform the cancer cell's

Graduate student James Hermus demonstrates a production robot based on the original MIT-MANUS design in the Eric P. and Evelyn E. Newman Laboratory for Biomechanics and Human Rehabilitation. Credit: John Freidah



behavior. Understanding whether tumor cells push or pull when they leave the capillary and the force interactions between endothelial cells and tumor cells represent potential therapeutic targets for preventing or minimizing metastasis.

"We can look at all these different tumor cell lines, treat the different cells, and see how that affects the rate at which the tumor cells escape from the vasculature and grow," says Kamm. This knowledge could open up new opportunities in treating cancer and even developing new immunotherapies.

## Treating Disease

Armed with more knowledge of how diseases grow and spread, researchers are better able to develop new ways to treat, and in some cases cure, disease. Among them is Assistant Professor Ellen Roche, who is taking a unique dual approach to treating heart disease using both mechanical and biological therapies.

"The idea is to mechanically assist the heart," explains Roche, who also serves as Helmholtz Career Development Professor at MIT's Institute for Medical Engineering & Science. "Rather than take over its function we just assist and augment it using a biomimetic approach."

Roche uses new techniques like soft robotics to develop devices that mimic both the tissue properties and the motion of the heart. One such device is a sleeve that wraps around the heart to assist with pumping (pictured on the cover). Soft robots like this sleeve use elastomeric materials and fluidic actuation to mimic an organ's movement. "By smartly designing simple fluidics channels and reinforcing soft materials in just the right way, you can achieve very complex motion with just elastomeric changes, and pressurized air or water," she says.

While working on mechanical therapies to treat things like congenital heart disease and heart attacks, Roche is also looking at how biological therapies can help in treating these diseases. She and her team are developing smart devices that provide localized drug delivery instead of systemic drug delivery.

"One of my main goals is to combine these mechanical and biological therapies and see how they interplay with each other," says Roche. Understanding how these different therapies interact could help determine the best timing sequence for maximum efficacy. With the help of collaborators in the cardiac surgery group at Boston Children's Hospital, Roche is creating and testing models for these therapies. "We really want to see if we can treat disease and recover function using polytherapy rather than just a mechanical or biological approach," she adds.

"One of my main goals is to combine these mechanical and biological therapies and see how they interplay with each other."

## Rehabilitation from Disease

In instances when disease is not detected or treated in time, researchers are developing tools that assist in the recovery process. From optimizing the design of prosthetic feet or building cheaper wheelchairs, mechanical engineers are finding ways to improve the quality of life for those living with the aftermath of disease. This work also includes tools and devices that can be used in physical rehabilitation. One such tool is the MIT-MANUS – a robot developed by Neville Hogan, San Jae Professor of Mechanical Engineering, to help stoke victims recover and regain mobility.

"They say no two snowflakes are alike, well no two stroke patients are alike either," says Hogan. "That makes the problem spectacularly complicated." Hogan has collaborated with neurologists and neuroscientists on understanding the process of recovery and basic motor control in the brain. He used this knowledge to develop robots that interact with stroke patients and help them regain control of their movements.

MIT-MANUS was originally designed to help restore motor function in stroke patients' shoulders and elbows. Patients strap their forearm into a brace attached to a robotic arm and grasp onto a controller connected to a video screen. On the screen, a video game provides patients with prompts to move their arm and wrist. If the patient is unable to fully move their arm on their own, MIT-MANUS provides guidance and assists their movements. The robot then tracks and stores this data for physical therapists and specialists to analyze.

"In clinical trials of MIT-MANUS we found that there was a reduction of impairment in joints exercised through use of the robot," adds Hogan. Over the years the scope of this robot-aided therapy for stroke victims has grown beyond hands and arms. Hogan and his collaborators have put together a robotic gym that helps deliver localized therapy to various limbs and joints throughout the body.

Whether it's constructing large robots like the MIT-MANUS to help rehabilitate stroke victims, tracking the miniscule movements of organelles in the cell, or using genetic circuits to create stem cells, mechanical engineers are shaping both our fundamental understanding of disease and the way in which doctors approach treatments and therapies.

Alumni Profile:

# Dennis Orgill, MD, SM '80, PhD '83

## Using Mechanical Forces to Make Wounds Heal Better

By Mary Beth O'Leary

To most, an operating room and a manufacturing plant are as different as any two places can be. But not to Dennis Orgill, MD, SM '80, PhD '83, who serves as Medical Director at Brigham and Women's Hospital's Wound Care Center and professor at Harvard Medical School. "To some degree when you do an operation it's much like manufacturing something in a factory," explains Orgill. "You want to have high quality control and be able to do it as efficiently as you can. Those engineering principles of process control are very important in surgery."

In the early '80s, Orgill earned his PhD in mechanical engineering at MIT through the Harvard-MIT Health Sciences and Technology (HST) program. Orgill's particular course of study within HST was the Medical Engineering and Medical Physics program – which combines a traditional mechanical engineering education with clinical and medical exposure.

This scaffold – or collagen skin graft – was invented by Professor Ioannis Yannas. Alumus Dennis Orgill developed a process of infusing the scaffold with healthy skin cells to promote a more effective regeneration. Credit: John Freidah

As a MechE student, it was only natural that Orgill gravitated toward the work of Professor Ioannis Yannas. Using his background in polymer science, Yannas had invented the first successful method of skin regeneration in burn victims along with his collaborator John F. Burke, MD at the Shriner's Burn Institute in Boston. For his PhD thesis, Orgill worked alongside Yannas to explore new methods of promoting tissue regeneration in a wound.

"Dennis is an unusually innovative person," says Yannas. "During his PhD studies, we would have lunches together where we would formulate ideas for the next steps in making skin regeneration more effective."

Orgill showed for the first time how to regenerate both the epidermis and the dermis of the skin. He developed a process of infusing a collagen skin graft – known as a scaffold – with healthy cells to promote regeneration. This first requires the harvesting of a healthy piece of tissue elsewhere on the patient's body. After being mixed in an aqueous solution, the cells are then placed in a centrifuge along with the collagen scaffold. The centrifugal force helps evenly distribute the cells within the scaffold.

When applied to the wound, the cell-infused scaffold was found to promote healing even better than the original scaffold Yannas and Burke had used. Rather than just regenerating the inner layer of the skin known as the dermis, these new cell-seeded collagen scaffolds promoted regeneration of the outer epidermis layer of skin at the same time.

After earning his PhD through HST, Orgill obtained his MD from Harvard Medical School. Over the course of nearly three decades working at Brigham and Women's Hospital, Orgill has continued his focus on finding ways to make wounds heal better. "My group has been conducting research on how mechanical forces are helping wounds to heal," says Orgill. "The concept of combining cells with the scaffold and adding mechanical forces is going to be a powerful way to move forward with skin regeneration."

Dennis Orgill (right) performs surgery at Brigham and Women's Hospital.

Orgill's medical research and practice have both been informed by his mechanical engineering background. "During my PhD program, I took various classes in subjects like finite element modeling and heat and mass transfer," explains Orgill. "These principles are incredibly important when looking at thermal burns and cooling devices."

According to Orgill, examining medical problems from an engineer's perspective has made him a better surgeon. "Mechanical engineering teaches a thinking process of how to analyze and tackle problems – in surgery we think in an analogous way," Orgill explains.

Orgill thinks in the future, operating rooms will be filled with more doctors with engineering degrees. The growing amount of biomedical engineering programs offered at universities seems to confirm this trend. "I think people will recognize that medicine is going to be better if we have more engineering incorporated into it as a way of thinking," says Orgill. "That's how we can solve quality, efficiency, and cost problems in the medical field."

Mechanical engineering teaches a thinking process of how to analyze and tackle problems – in surgery we think in an analogous way.

Student Spotlight:

# Sally Miller SB '16

## Turning Any Room into an OR

By Mary Beth O'Leary


Graduate student Sally Miller with the latest prototype of SurgiBox, a localized surgery-ready environment which adheres to the patient's body. Credit: John Freidah

Dust, dirt, bacteria, flies – these are just some of the many contaminants surgeons need to worry about when operating in the field or in hospitals located in developing nations. Doctors and patients in developed areas meanwhile typically have access to the tools and facilities required to facilitate sterile surgery. However, according to a 2015 study in *The Lancet*, five billion people don't have access to safe, clean surgical care. Graduate student Sally Miller SB '16 is hoping to change that with a product called SurgiBox.

"The idea of SurgiBox is to take the operating room and shrink it down to just the patient's size," explains Miller. "Keeping an entire room clean and surgery-ready requires a lot of resources that many hospitals and surgeons across the globe don't have."

Upon starting her master's degree at MechE, where she also received her bachelor's, Miller connected with Daniel Frey, professor of mechanical engineering and Faculty Research Director of MIT's D-Lab. Frey had been working on the concept of SurgiBox with Debbie Teodorescu, its founder and CEO who graduated from Harvard Medical School and acted as a D-Lab Research Affiliate. Having just won the Harvard President's Challenge grant of $70,000, the SurgiBox team looked to hire a mechanical engineering graduate student who could help enhance its design.

"We were looking for a way to accelerate the project," explains Frey, who also serves as Miller's advisor. "At MIT, grad students can really deepen a project and move it forward at a faster pace."

That's where Miller comes in. "The first thing I did was assess the design they already had but use my mechanical engineering lens to make the product more affordable, more usable, and easier to manufacture," she explains.

Miller found inspiration in class 2.75, Medical Device Design. For the class project, she visited the VA Medical Center where she watched a pace maker surgery. During the surgery, doctors placed an incise drape – an adhesive, antimicrobial sheet infused with iodine – on the site of the incision.

"Watching the surgeons that day I realized 'Oh, I can use this adhesive drape idea for SurgiBox,'" says Miller.

In addition to incorporating adhesive drapes at the point of incision, Miller has redesigned the structure of SurgiBox. The original design had a rectangular frame that sealed to the patient at the armpit and waist. The frame held up a plastic, tent-like enclosure with a fan and high efficiency particulate air (HEPA) filter that removes 99.997% of contaminants. Miller realized, to make SurgiBox more portable and cost effective, she had to get rid of the frames. With her new design, SurgiBox now consists of an inflatable tent. The positive pressure on the inside from the HEPA filtered air gives the surgical site its structure.

This structural change marked a turning point in SurgiBox's development. "Now the patient doesn't have to be in the SurgiBox, rather the SurgiBox is on them," explains Frey. "I thought that was a big breakthrough for us."

Teodorescu agrees. "Sally is stunningly capable at both manual and digital forms of technical drafting," she says. "Because of her designs, a key part of SurgiBox now fits into a Ziploc bag." This latest iteration of SurgiBox isn't just smaller and more efficient – it's also more sterile. SurgiBox now meets the same germproof and blood-proof standard as surgical gowns used by doctors treating Ebola patients.

The next step for the SurgiBox team: user testing. In addition to continuing particle testing, the team will partner with local Boston-area hospitals to test the ergonomics of the design and ensure it aligns with surgical workflows. After that, the team will test its efficacy at partner hospitals in developing nations where the technology is most needed.

As for Miller, after graduating with her master's in January she is hoping to start a career in product design. "Working on SurgiBox during my masters as well as undergraduate classes like 2.009, Product Engineering Processes, gave me hands-on experience creating a product with real-world application," says Miller. "I'm open to working on products in a number of fields and am excited to see what my future holds after MIT."

Keeping an entire room clean and surgery-ready requires a lot of resources that many hospitals and surgeons across the globe don't have.

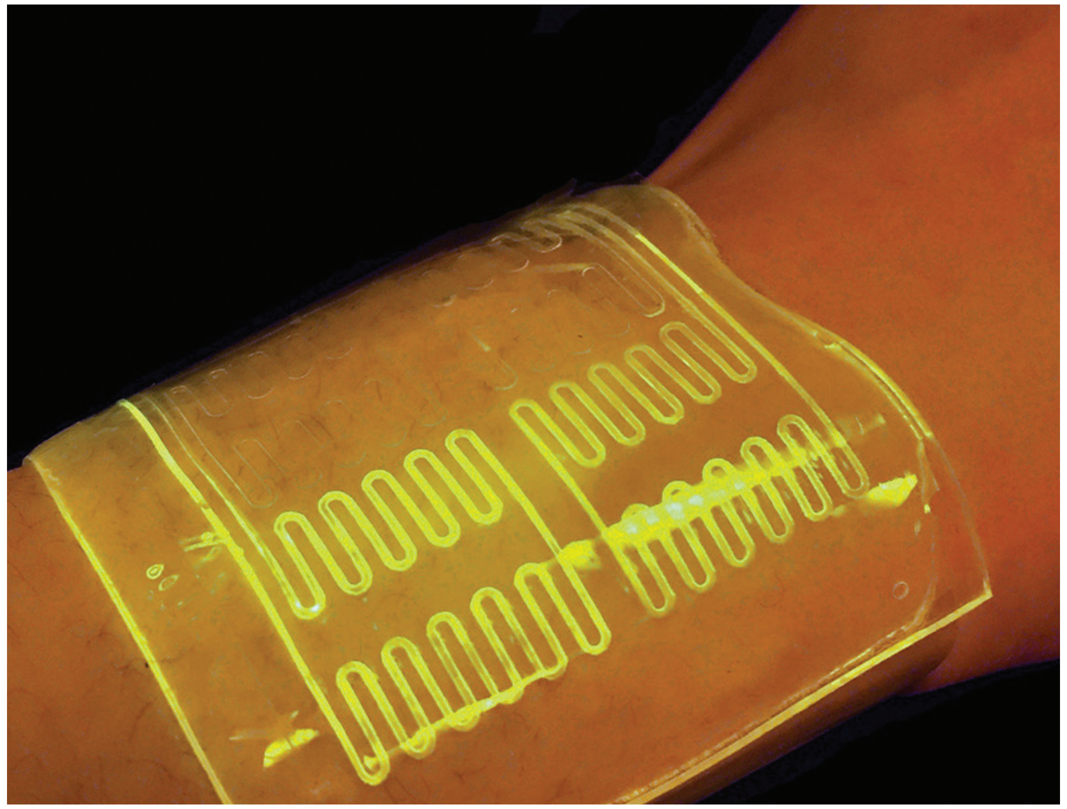
Talking Shop:

# Associate Professor Xuanhe Zhao

## Making Comfortable and Effective Medical Materials

The human body is mostly made from soft materials. Our skin, muscles, and tissue are pliable, but the materials we use to interact with them are often rigid. Catheters, insulin pumps, and IV tubes are composed of hard materials that frequently cause discomfort, and in some instances infection. Noyce Career Development Professor Xuanhe Zhao wants that to change.

As Director of the Soft Active Materials Laboratory, Zhao and his team are developing materials that can better interact with the human body. These materials can be used to design and create more comfortable and effective medical devices, sensors, and equipment.



This smart hydrogel bandage designed by Xuanhe Zhao's team has been infused with cells that light up when in contact with certain chemicals. Credit: Hyunwoo Yuk

**You have a diverse educational and training background. How has this shaped your research?**

I have a bachelor's in electrical engineering, a master's in materials engineering, a PhD in mechanical engineering, and I did a post-doc in biomedical engineering. My education has inspired me to ask interdisciplinary questions about things that are impactful for human society. I then use tools from my different areas of study to solve those questions.

**When did you start looking at medical applications for the materials you design?**

During my PhD study, I worked on the mechanics of soft materials. Since the human body is a composite of different types of soft materials, I was interested in the connection between human health and the materials used in medicine. Gradually I got interested in interfacing the human body with external technologies. That has become my major research interest – using mechanical engineering to improve the way materials and devices interact with the body.

**Much of your research focuses on hydrogels. How do hydrogels help devices interact with the body?**

A hydrogel is a polymer network infiltrated with water. If you look at the human body, except for teeth, bone, and nails, most components are hydrogels with various physiological and mechanical properties. That's the primary reason we are interested in hydrogels. In my group, we use biopolymers to design the hydrogels to be tough, robust, or adhesive depending on how the material is going to interact with the body.

In my group, we use biopolymers to design the hydrogels to be tough, robust, or adhesive, depending on how the material is going to interact with the body.

**What types of medical applications have you found using these materials?**

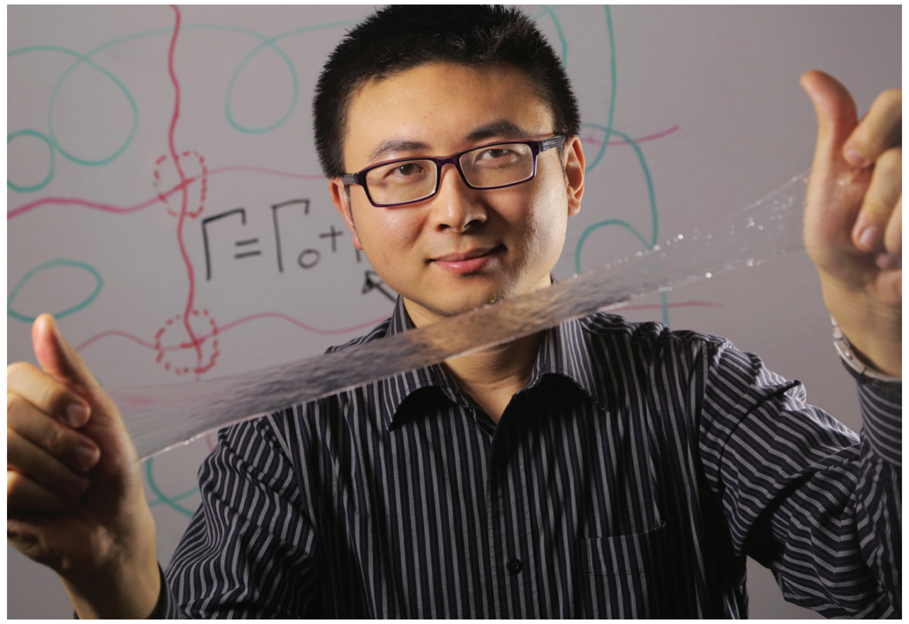
We have used this technology on medical materials and devices that interact with the human body in a number of ways. From bandages that rest on the skin to catheters which enter cavities in the body and most recently to implantable devices like glucose sensors. They all interact with the body in very different ways, so our challenge is to understand this interaction and alter the mechanics of the materials to design better devices for these specific uses.

**Could you explain how you went about designing some of these devices?**

Certainly – for the bandage it has become clear that there is an opportunity to develop smart bandages that detect different physiological conditions on the skin and release drugs in response to those conditions. Detecting things like temperature and bacteria requires the bandage to be embedded with sensors. We designed an interface where the hydrogel material, which is soft and comfortable on the skin, bonded with the sensors so they can sense conditions on the skin and deliver drugs accordingly.

Designing catheters presented a different problem. Catheter blockage and infection is a major cause of rehospitalization. Existing catheters are made of rigid elastomers that can easily get infected by bacteria growing inside them. They also are not lubricated and cause irritation. Again, we designed a catheter using hydrogels, which is more similar to human tissue than the elastomer. Since hydrogels are permeable to viruses, we had to create a hydrogel-elastomer hybrid to make the catheter impermeable but still soft and slippery. This results in a device that is both more comfortable and safe.

As for implantable devices – things like neuroprobes, which can be inserted into the brain to stimulate tissue and measure signals, or glucose sensors, which can be implanted for continuous monitoring of blood sugar levels – the primary obstacle is how the body views them. They are seen as a foreign object and are attacked by our immune system. We are developing gel-based materials that can significantly reduce the foreign body reaction. To me, this is the next big frontier in using hydrogels to design medical devices.



Class Close-Up:

# 2.75 Medical Device Design

By Mary Beth O'Leary

Maeve Devlin (left) and Oumaima Makhlouk (right) meet with their advisor Alex Slocum. Credit: John Freidah

Dr. Matt Bianchi had a problem. As Chief of the Division of Sleep Medicine at Massachusetts General Hospital, he needed a better way to diagnose sleep disorders. To make a diagnosis, a patient needs to come into a sleep lab and be attached to a number of devices. This setting is hardly representative of the patient's normal sleep environment. Bianchi needed a way to track and measure sleep at a patient's home.

Bianchi outlined this problem when presenting to the students of class 2.75, Medical Device Design. The class brings clinicians from Boston-area hospitals and MIT students together to design prototype devices that help solve problems identified in the clinic.

"We use the design of medical devices as a vehicle to teach a deterministic design process," says course instructor and Walter M. May and A. Hazel May Professor Alexander Slocum.

Medical devices offer students an opportunity to work on something they can personally relate to since at some point in their lives, either they or a loved one has needed to use a medical device. "The more we can do to make medical devices simpler, lower cost, and better performing, the more we not only help the world, but ourselves," Slocum explains.

Before the course begins in the fall semester, Slocum and his teaching team review submissions from local physicians – as well as some researchers and industry partners – who propose a problem for a team of students to work on. These physicians, like Dr. Bianchi, present to all the students in the class, who then choose the project that most appeals to them. With the physicians paired with a group of eager students, the design process can begin.

"We coach students to say to physicians, 'Look we are going to learn from your clinical skills and we want you to learn from our engineering skills,'" adds Nevan Hanumara, co-instructor of the class. "When the partnership works it's beautiful."

The projects physicians have worked with students on throughout the years have been incredibly diverse. One team worked with a clinician who was at the finish line of the 2013 Boston Marathon bombings and saw first-hand the need for a better tourniquet that could quickly be applied by first responders, or an injured individual, such as a soldier on the battlefield, themselves. Another team had a more electrical focus, developing a wearable device that measured blood pressure continuously.

Professor Alex Slocum (right) works with students Alban Cobi and Steven Link, who are developing an adjustable phantom for radiotherapy validation. Credit: John Freidah



Alexander Mok (left) tests his group's cardiopulmonary assessment device with Exercise Physiologist Casey White (right) in the Cardiopulmonary Exercise Testing Laboratory at Massachusetts General Hospital. Credit: Teresa Lin

The expertise of the students working on these projects are as diverse as the devices themselves. "A key element in this class is we have students from very different backgrounds – mechanical, electrical, health sciences," says Slocum.

This diversity of backgrounds is something graduate student Jonathan Miller experienced first-hand this past semester. A graduate student in Integrated Design & Management, his team also consisted of two mechanical engineering undergraduates, an electrical engineering undergraduate major, and a graduate student participating in the Harvard-MIT Division of Health Sciences and Technology (HST) program. The team worked together on developing a device that can enable more patients to receive dialysis in-home, rather than at a clinic.

"It's pretty remarkable that you can take five students with very different backgrounds who weren't previously exposed to the complexities of dialysis and pair them with the right kind of mentorship so we can develop useful solutions for people undergoing treatment," says Miller.

This mentorship and guidance extends beyond device design and the end of the course. "We also focus on professional development skills including the softer skills of team dynamics, working with vendors, and time management," adds Hanumara. HST graduate student Benjamin Maimon found this focus on skills useful. "One thing the class does that's unique from other classes is they give you a real budget and a real problem," says Maimon. His project in the course lead to the development of Recon Therapeutics, a start-up that simplifies the process of mixing powdered drugs with a solvent using new drug discovery technology.

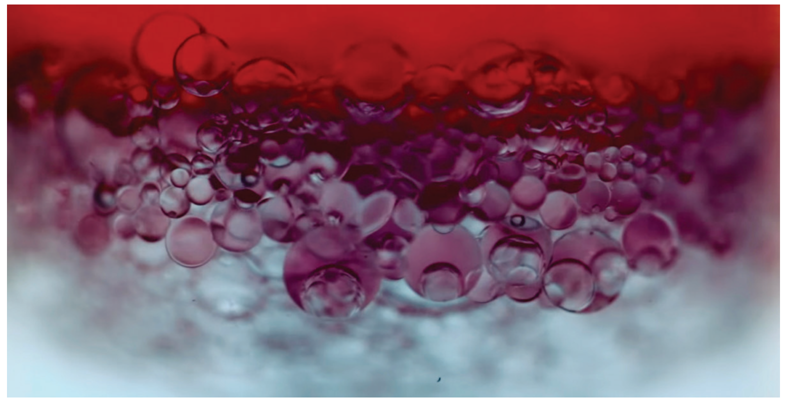
The marriage of design and professional skills, as well as the collaborations with some of the top medical minds in the country, have turned the course into an incubator for products, start-ups and patents, like Recon Therapeutics.

Such was the case when Dr. Bianchi presented his sleep disorder diagnosis problem back in Fall of 2010. Then a mechanical engineering senior, Thomas Lipoma, along with roommates and fellow 2.75 students Carson Darling and Pablo Bello collaborated with Bianchi on developing a wearable shirt embedded with sensors that patients could wear in the comfort of their own beds. Using an algorithm, the device was then able to help doctors diagnose certain sleep disorders.

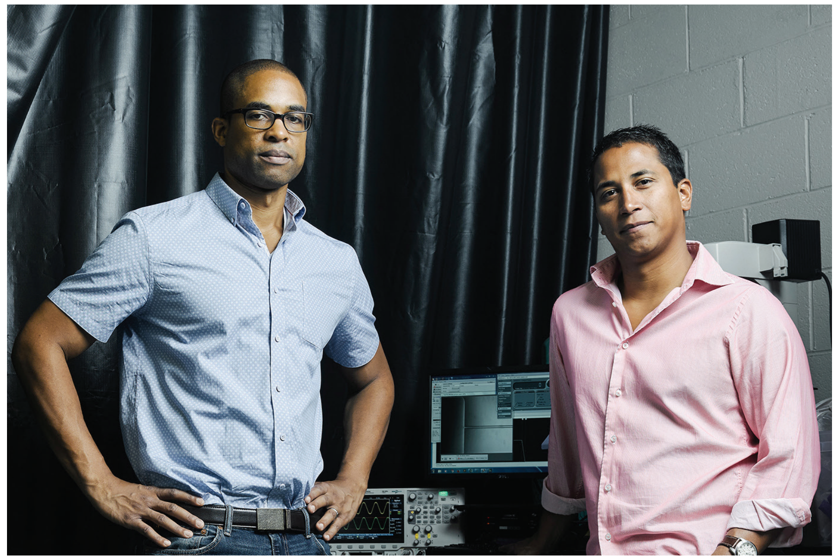
Continuing work on the product after graduation, the team founded Rest Devices, Inc. The company now produces Mimo, a onesie embedded with sensors that can be used by parents to track their infant's vital signs such as respirations, heartbeat, and temperature.

Lipoma and his co-founders credit class 2.75 with first giving them the tools they needed to take their project from a concept to a company. "I think by far it's one of the best places on campus to generate new ideas that actually have impact on something in the world," says Lipoma. "There is just a lot of expertise around you to help you develop really unique solutions to problems in the medical field."

# News & Awards



Associate Professor Kripa Varanasi's team has developed a new method of mixing oil and water. Credit: Varanasi Lab



Associate Professor Cullen Buie (left) and Research Scientist Paulo Garcia (right) are co-founders of the start-up Kytopen. Credit: Doug Levy/The Engine

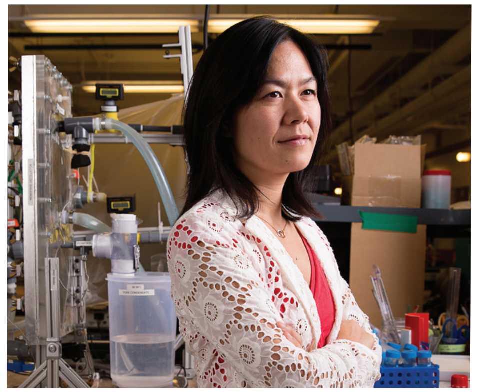
## Departmental and Research News

• Evelyn Wang, the Gail E. Kendall Professor and director of MIT's Device Research Laboratory, has been named associate department head for operations in the Department of Mechanical Engineering.

• MIT's Department of Mechanical Engineering was ranked as the No. 1 mechanical engineering undergraduate program by *US News & World Reports*.

• In Fall 2017, MIT launched the New Engineering Education Transformation (NEET) initiative which is rethinking engineering education by offering students two pilot cross-departmental threads: Living Machines and Autonomous Machines.

• Research Scientist Joshua Siegel PhD '16 and Professor Sanjay Sarma have created a smartphone app that provides diagnostic information about a car's health – from tire pressure to air filters and spark plugs. Their work was published in the journal *Engineering Applications of Artificial Intelligence*.



Professor Evelyn Wang was named Associate Department Head in September 2017. Credit: Bryce Vickmark

• Associate Professor Kripa Varanasi has developed a new condensation-based method of mixing oil and water which may allow them to remain stable for long periods. The process, which could be used in pharma, cosmetics, and food, was described in *Nature Communications*.

• Takeda Pharmaceutical Company Limited announced a collaboration to develop and commercialize Portal Instruments' needle-free drug delivery device developed by Professor Ian Hunter.

• To help the 1.3 billion people living without regular access to power, Associate Professor Konstantin Turitsyn developed a framework, published in *Control Systems Letters*, that guarantees stability in microgrids supplying power in developing countries.

• Prolific inventor Martin Prince SB '80, SM '82, PhD '88 has endowed two funds for mechanical engineering students. The Prince Innovation Prize will be given to an undergraduate with a promising patent or patent application. The Prince Innovation Fellowship will be given to a graduate student who is the first named inventor on a promising patent or patent application.

## New Faculty

• Assistant Professor Willem M. van Rees recently joined MechE from Harvard University. His research combines computational fluid dynamics and structural mechanics with modern machine learning to design ocean propulsion and energy harvesting systems.

• Assistant Professor Ellen Roche recently joined MechE from Harvard University. Her research focuses on applying novel manufacturing technologies to translational medical devices and developing devices along the translational path from concept to clinic.

## Faculty Awards

• Professor Lallit Anand has been awarded the 2018 William Prager Medal by the Society of Engineering Science for his outstanding research contributions to large deformation plasticity theory.

• Professor Evelyn Wang was awarded The Gustus L. Larson Memorial Award for outstanding achievement in mechanical engineering by the American Society of Mechanical Engineers.

• Professor Alexander Slocum won the Capers and Marion McDonald Award for Excellence in Mentoring and Advising, given to a faculty member who has demonstrated a lasting commitment to personal and professional development. He was also recently elected to the National Academy of Engineering.

• Kytopen, co-founded by Associate Professor Cullen Buie, is among the first seven start-ups backed by The Engine, a venture launched by MIT that will support 'tough-tech' companies. The Kytopen team has developed a new wave of genetic engineering, delivering DNA to bacterial cells up to 10,000 times faster than current state-of-the-art methods.

• The Massachusetts Manufacturing Innovation Initiative and Governor Charlie Baker awarded Professor Harry Asada a $2 million grant to develop Teach-Bot, an innovative robotics instructor and demo machine that interacts with the learner.

## Student Awards

• Senior Matthew Chun has been selected as a Rhodes Scholar. He will begin postgraduate studies at Oxford University next fall with the goal of advising organizations that bring life-improving technologies to countries around the world.

• Jorlyn Le Garrec '17 has been awarded a 2017 Fulbright grant. She will study underwater robotics and pursue a mechanical engineering master's degree at the University of Auckland.

• Graduate student Kevin Simon has been named one of *Manufacturing Engineering*'s 30 Under 30 for his focus on "problems with impact" – including developing low-cost irrigation technologies.

• Graduate students Maher Damak and Karim Khalil from the Varanasi Research Group were both named as one of the *Forbes* 30 Under 30 in Energy for co-founding Infinite Cooling, which recaptures water vapor that escapes from cooling towers at power plants. PhD Candidate You Wu was also named one of the *Forbes* 30 Under 30 in Manufacturing & Industry for founding Pipeguard Robotics, which manufactures a robot that travels through water pipes to detect leaks.

PhD candidate Kevin Simon was honored by *Manufacturing Engineering* for his development of low-cost irrigation technologies to meet India's agricultural needs. Credit: Kevin Patrick Simon

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