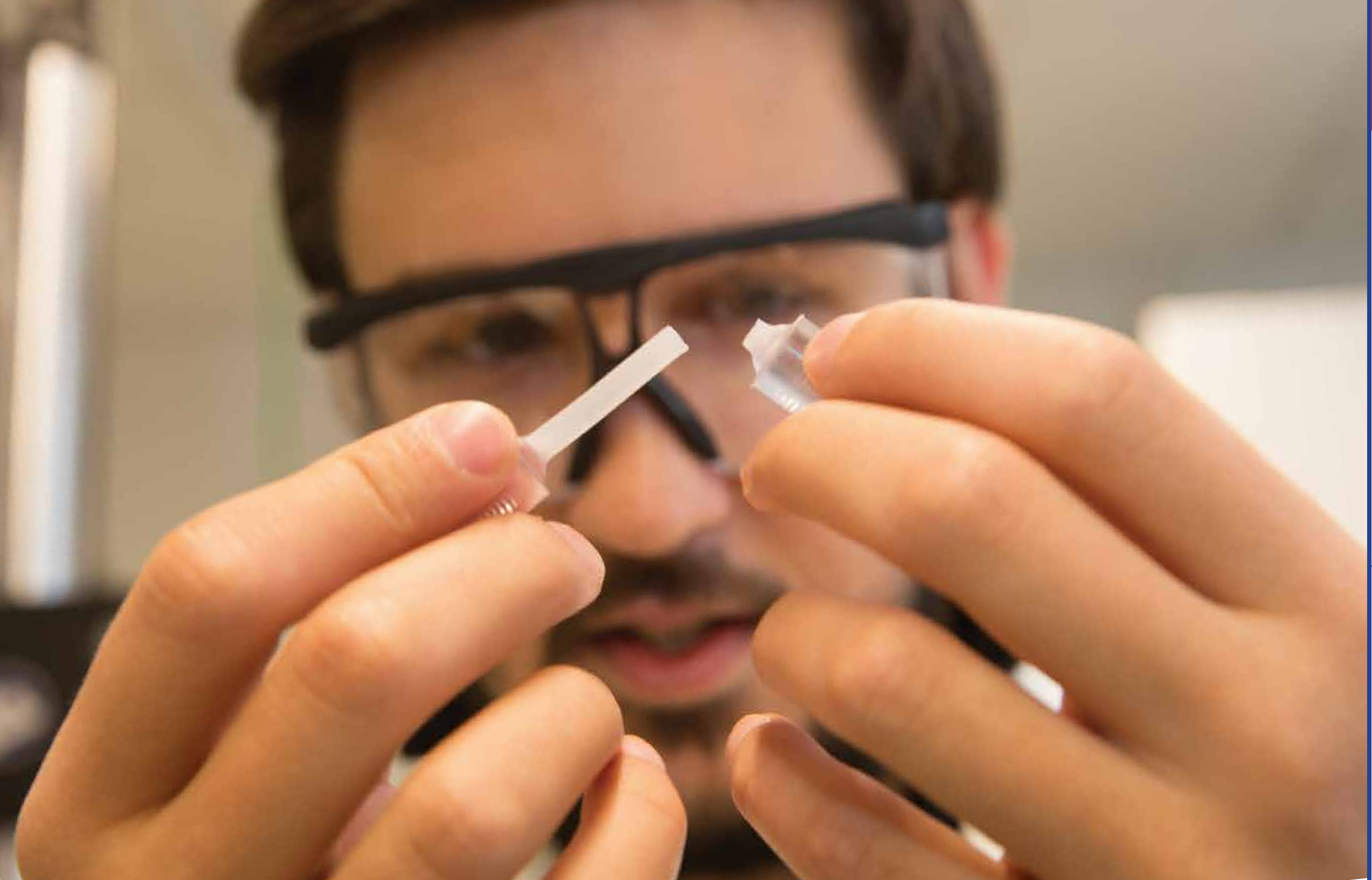
NEW JERSEY INSTITUTE OF TECHNOLOGY

RESEARCH

LINKING LABORATORIES TO LIVES

NJIT
New Jersey Institute of Technology



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From the Senior Vice Provost for Research

With quantum leaps in materials science and engineering research over the past two decades, we are now able to manipulate properties at the nanolevel, engineer biological tissues and create new devices to harness and deploy energy in powerful ways.

Not a moment too soon, these crucial advances will help replenish our declining water supply, capture greenhouse gases, allow large-scale battery-powered devices, and restore and improve our crippled urban infrastructure. Coupled with simultaneous discoveries in nanoscience, materials research is revolutionizing technology-based markets as diverse as pharmaceuticals, medical devices and sensors, information technology and data storage.

At NJIT, we are embracing this research across sectors, from advanced cements and composites and smart, nanoengineered concrete, to 3D-printed biological scaffolds and tiny biosensors, to membrane technology that filters water and air and delivers drugs with cost-effective precision.

In this issue of the New Jersey Institute of Technology (NJIT) Research Magazine, we focus first on the work of three hubs in our growing materials science and engineering cluster, where engineers, physicists, mathematicians and chemists collaborate on projects that blur the borders of all of these disciplines.

We first highlight the efforts of tissue engineers who work closely with the medical and rehabilitation communities to restore the neural pathways of ruptured spinal cords and to regenerate damaged heart and pancreas cells. Secondly, we focus on engineers who are creating their own novel compounds to enhance fuel capacity, propel space vehicles and neutralize biological weapons. Lastly, we present the work of our Analytical Chemistry and Nanotechnology Laboratory, which re-engineers water filtration systems, batteries and solar cells with nanomaterials that boost performance.

Elsewhere in this issue, we include snapshots of our current research in many other areas: a biomedical engineer who develops novel methods for remediating pollution on Native American lands; a physicist who is developing materials and devices to manipulate energy waves; and a pioneer in membrane technology whose inventions span sectors, from pharmaceutical engineering to water desalination.

With investments in advanced facilities, instrumentation, fabrication technology and new faculty, we are expanding our role in the development and translation of pre-commercial prototypes of advanced materials, sensors and devices. As NJIT's innovation and entrepreneurship ecosystem expands, we also look to accelerate their path to market.

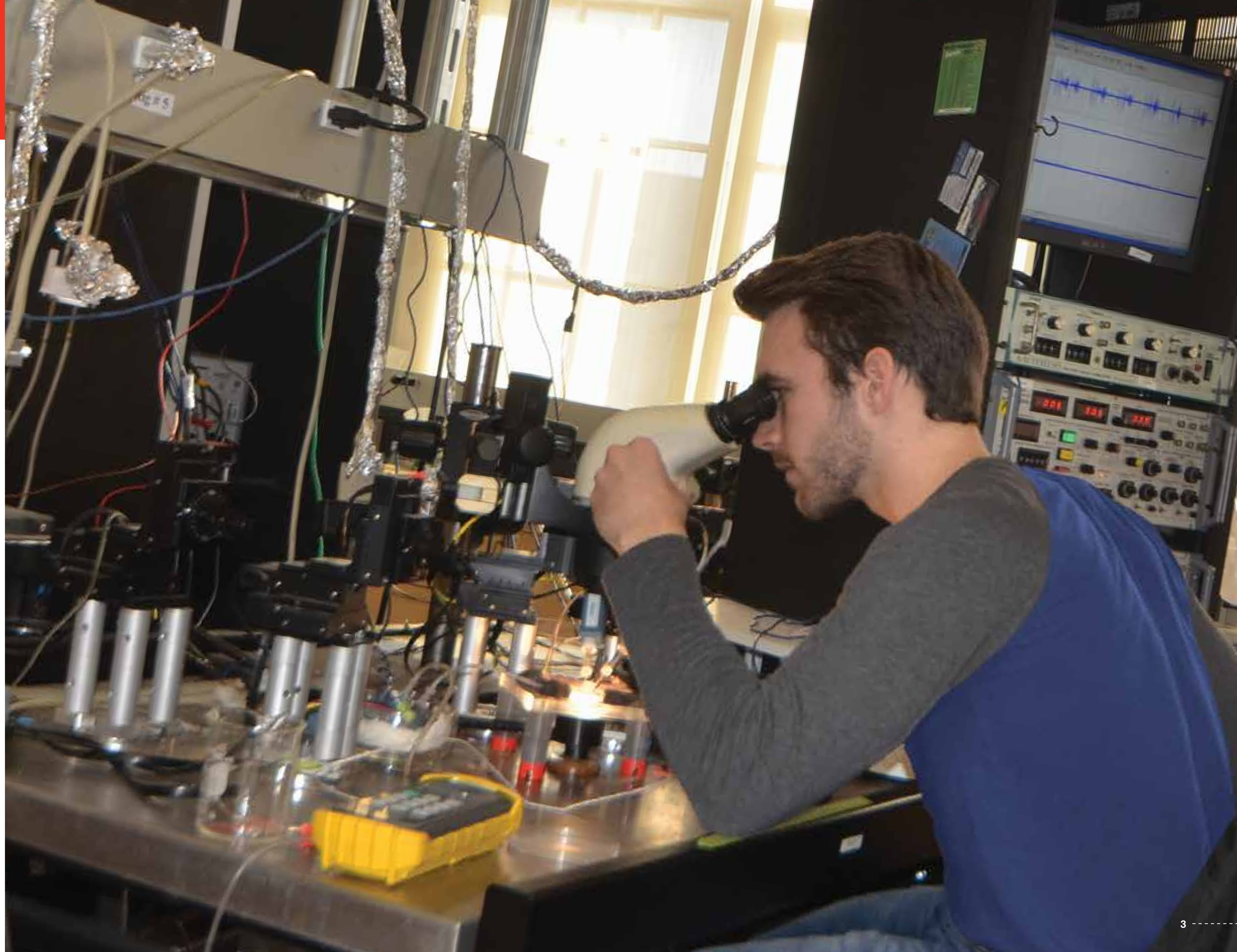
Among other resources, the university's new Life Sciences and Engineering Center provides our researchers with state-of-the-art materials-characterization equipment, including a scanning electron microscope, a tunnel electron microscope and an X-ray diffraction spectroscope. Renovations to the former NJIT Microfabrication Research Center will offer micro- and nanofabrication facilities for the development of semiconductor and microfluidic sensors and devices. Makerspace at NJIT, which opened earlier this year, is already producing custom-designed equipment for experiments led by faculty and students.

And finally, our inventors are beating new paths to market by leveraging their research through an expanding universe of outside technology company partners, commercialization grants and venture capital funding. In one exciting example of translational research, mechanical engineer Eon Soo Lee is developing a nanotechnology-enhanced biochip that would give doctors and patients in a range of health care settings the ability to detect deadly diseases such as ovarian cancer and pneumonia early in their progression.

Rounding out our innovation ecosystem, the more than 90 startup and early-stage technology companies at NJIT's Enterprise Development Center increasingly collaborate with us, while providing a training ground for would-be entrepreneurs among our student body. Our New Jersey Innovation Institute connects us with tech-based companies throughout the state and country.

Atam P. Dhawan

Senior Vice Provost for Research
Distinguished Professor of Electrical and Computer Engineering



From 3D-Printed Tissues to New Energetic Compounds, Materials Science Is Transforming Modern Life

Twenty-five years ago, the discovery of carbon nanotubes ushered in a new era in materials science. About 10,000 times smaller than a human hair in diameter, these tubular sheets of graphene possess a unique set of properties – they are incredibly lightweight and yet stronger than steel, more durably conductive than copper, highly flexible and inexpensive to manufacture.

Not only do they transform existing materials, adding resilience and functionality to polymers and structural composites in golf balls, boat hulls and industrial coatings, they improve the performance of devices such as batteries, radio antennae and water filters. And they are now poised to give rise to futuristic applications such as wearable batteries threaded through garments, advanced solar cells and biosensors.

As is the case with many of the groundbreaking advances in materials science, the detection of carbon nanotubes was made possible by the electron microscope and other powerful new imaging tools, which allow scientists to characterize properties of biological and industrial materials at the macro- and nanoscale, and to make new ones.

This explosion of knowledge has in turn led to productive partnerships between engineers and scientists, theoreticians and applied researchers, and academics and clinicians, who work together to develop critical new health care devices, efficient industrial processes and new materials altogether. At NJIT, the growing cluster of researchers who develop new materials, nanomaterials and the technologies that incorporate them includes physicists, chemists, biomedical engineers and mathematicians.

Somenath Mitra, a chemist, works with environmental biologists to study nanomaterials that he uses in membranes to filter water, control pollution and boost energy storage. By manipulating materials at the nanoscale – adding tiny particles of scarce, expensive metals such as platinum to carbon nanotubes to enhance conductivity, and mixing carbon nanotubes to polymers to boost absorption – he is able to reduce the costs and improve the performance of environmental and energy technologies.

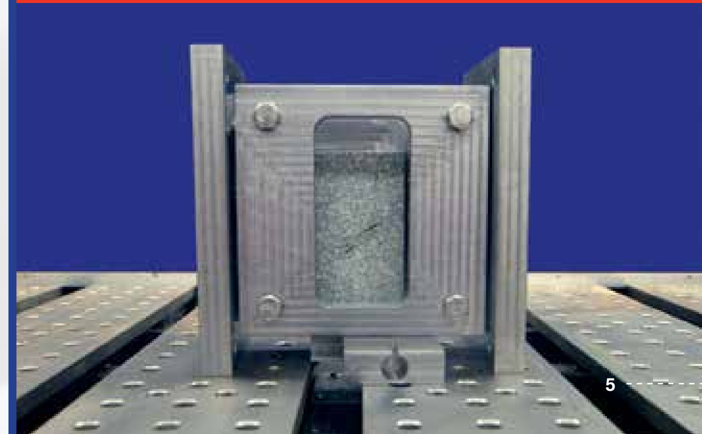
Treena Arinzeh, a biomedical engineer, develops new piezoelectric polymers to incorporate into biological scaffolds designed to spur new cell growth in spinal and bone tissues. Between them, biomedical engineers **Vivek Kumar** and **Alice Lee** develop new tissues for the mouth, internal organs and vasculature. **Murat Guvendiren**, a chemical engineer, 3D prints three-dimensional models of body parts based on CT scans that surgeons study before operations. Alumnus **Robert Cohen**, a biomedical engineer, has devised new methods for manufacturing metal-polymer hip and knee joints that doctors are now implanting.

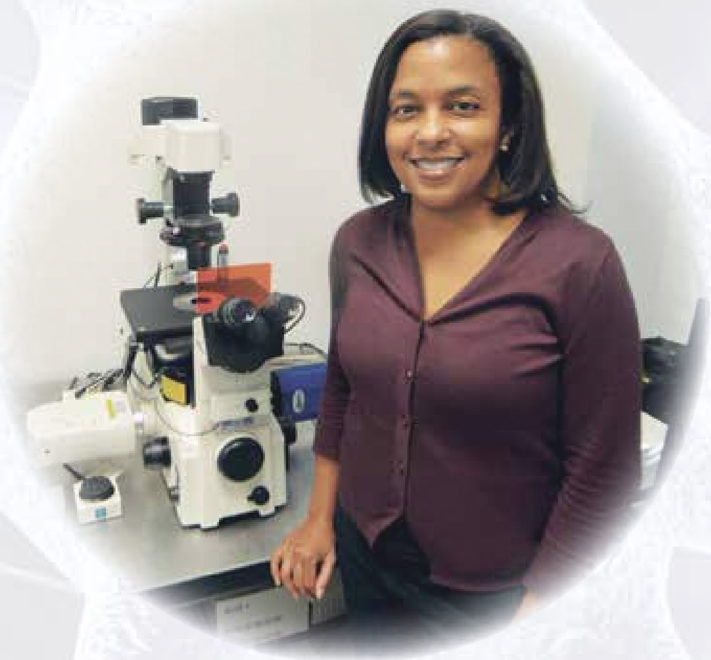
In the quest to free information networks from dependence on electricity so that they can compute at the speed of light, physicist **Andrei Sirenko** collaborates with materials scientists to identify replacements for silicon-based technology. He is currently exploring a class of magnetoelectric oxides with unusual properties that could potentially harness photons rather than electrons.

Physicist **Camelia Prodan** and chemical engineer **Edward Dreizin** are developing new materials. Prodan is exploring the mechanisms that store energy at the edge of cells to design a new class of materials and devices that manipulate energy waves through physical patterning, either blocking, channeling or dissipating them. Dreizin is making highly energetic materials by creating novel metastable compounds through milling at the nanoscale.

ABOVE: Murat Guvendiren's Instructive Biomaterials and Additive Manufacturing Laboratory bioprints biomedical devices and tissue scaffolds.

ABOVE: Physicist Camelia Prodan's research team creates experimental platforms to test the effects of patterning on the propagation of vibrational energy. BELOW: Civil engineer BRUNO GONCALVES DA SILVA built a device to study the way rock fractures under real-world field stress conditions.





Rebuilding Spinal Cords With an Engineer's Toolkit

Treena Arinzeh, director of NJIT's Tissue Engineering and Applied Biomaterials Lab, is building a scaffold, composed of an energetic polymer, that will coax nerve cells to extend their axons over the damaged section of a spinal cord.

Like an earthquake that ruptures a road, traumatic spinal cord injuries render the body's neural highway impassable. To date, there are neither workable repairs nor detours that will restore signal flow between brain and limbs, reversing paralysis.

"The problem is that nerve cells do not regrow," explains **Treena Arinzeh**, director of NJIT's Tissue Engineering and Applied Biomaterials Lab. Her solution is to build a bridge, made of an energetic polymer, that will coax nerve cells to extend their axons over the damaged section.

Arinzeh's repair strategy combines neural cells to regenerate nerve tissue with a scaffold of piezoelectric material, which produces an electrical charge. The advantage of this "smart" material, which is also used in sonar and sound technologies, is that it generates its own charge and does not require an external power source.

"Axons – the fibers that transmit messages – can potentially travel long distances if given the right cues to regrow. We knew that an electrical charge could direct this growth," Arinzeh says. "Some tissues in the body are naturally piezoelectric. What we did was to create a fibrous material that is similar, but with a higher charge to stimulate growth."

With funding from the U.S. Department of Defense, the technology is being put to the test in preclinical studies at the Miami Project to Cure Paralysis, a Center of Excellence at the University of Miami's Miller School of Medicine, where Arinzeh is working with **Mary Bunge**, a neuroscientist, as well as a former student. They are testing the efficacy of injecting Schwann cells from the peripheral nervous system, which produce the myelin sheath around nerve axons, in combination with the piezoelectric scaffold, for spinal cord repair. The Schwann cells' job is to restore existing cells by stimulating them to extend their axons.

The Miami Project is currently in phase I clinical trials with humans as well, using Schwann cells and piezoelectric scaffolds. "We hope to improve the cells' survival and their effectiveness when implanted into the spinal cord," Arinzeh says.

"The nice thing about Schwann cells is that they're readily accessible from low-risk sites like limbs. I think of them as 'facilitator cells' because they provide the signals that prompt axons to grow and reach their targets – other neurons."

In the pre-clinical studies, Arinzeh found that implanted scaffolds with Schwann cells would extend over a five-millimeter gap in the spinal cord. "The cells survived and were getting good growth – wrapping themselves around the growing axons as the axons extended along the scaffold."

The primary conventional remedy to spinal cord trauma is to reduce inflammation with drugs. There have also been regenerative medicine strategies which involve injecting cells with growth factors, or growth factors alone, into the spinal cord in the hopes of stimulating new growth, but they have not been successful. Arinzeh says that engineering approaches are gaining more acceptance.

"No technology has been effective so far, and so we're taking it a step further, introducing biomaterials with an electrical charge. We've known in the biomedical world that electrostimulation can cause nerve cell growth – we've seen this with bone and cartilage tissue – so we set about to identify a polymer with piezoelectric properties. We found it in a material used for sutures, which is biocompatible and promotes nerve growth," she explains. "We're looking for some recovery of function. If we can show that, it would be a significant leap."

For the community of scientists, engineers and clinicians determined to treat paralysis, the stakes are high. Success will hinge upon contributions from all of their domains.

"With bone and cartilage, we're relying on the scaffold to stimulate the body's own cells to regrow tissue, but the biological factors driving the formation of neural tissue in the spinal cord appear to be more complex," Arinzeh notes. "To induce nervous tissue to not only regrow across the lesion, but to reconnect with the rest of the spinal cord, may require a combination of scaffolds, cells and growth factors."

A Heart Attack in a Petri Dish

In petri dishes in her laboratory, ALICE LEE is developing colonies of cardiac cells, formed into chambers, that pump and contract like a human heart. Derived from stem cells, these primitive organs will help her achieve a research milestone: to observe in microscopic, real-time detail how the heart repairs itself after injury.

She must first induce an "attack" by damaging the tiny proto-hearts with a frozen rod, thus mobilizing sequential, cell-based repair crews that clear the injury site of debris, and then in a second phase, recruit materials and tools from the neighboring tissue to mend the damage.

"By developing diseased-tissue models, we're hoping to gain insights that will allow us to improve diagnoses and therapies for cardiac diseases," says Lee, an associate professor of biomedical engineering.

"What is unique about these experiments is the opportunity they provide to see how different cell types in the heart interact during the repair process in the immediate aftermath of a heart attack – the period that offers the best chance for successful cell-therapy interventions," she notes. "Better understanding of diseased tissue can help us to predict how stem cells used in cell-based therapy will integrate and function in the body."

Medical researchers have had little success with these therapies so far, because the injected cells drift away from the injury and fail in their task to rebuild tissue.

"They don't stick to the site, and eventually they die," says Lee, who recently won a five-year Faculty Early Career Development (CAREER) Award from the National Science Foundation to advance cell-based therapies. "We're trying to figure out what biological mechanisms will guide the stem cells used in therapy to the right place and foster their growth there."

A crucial element of this process is ensuring there are enough blood vessels to supply the tissue with the nutrients and energy it needs to grow.

"In order to build what's physiologically correct, we must incorporate vasculature, a functioning network of vessels to feed the new organ cells and permit their growth, and we are still searching for the best strategy to create this tissue," she says. "It's difficult to do outside of the body without proper blood flow and signals from other cells and tissues." She is currently investigating the role of tissue-specific vascular cells and improving a device she created to host vessel-formation experiments.

In his Reactive and Energetic Materials Laboratory, Edward Dreizin is creating novel energetic compounds by milling together distinct metal-based materials into tinier and tinier bits.

In the Search for New Materials, an Engineer Makes His Own

In the search for new, highly energetic materials that pack a wallop in small amounts, **Edward Dreizin** is synthesizing his own.

In his Reactive and Energetic Materials Laboratory, he creates novel compounds, such as modified metal, reactive nanocomposite and mechanically alloyed powders, by milling together distinct metal-based materials into tinier and tinier bits.

"Milling causes a chemical reaction through mechanical means, as when rubbing flint against steel causes a spark," notes Dreizin, distinguished professor of chemical engineering. "Instead, we're creating new materials. They're nanocomposites – we're not chemically combining them, but rather mixing them together in fine scale. The molecules remain unchanged, but the compounds are metastable; they will react chemically if prompted by external forces such as impact, shock or heat over certain thresholds."

His goal is to create metal-based materials with combustion and accelerated reaction rates exceeding those of existing fuels in advanced propellants, explosives and pyrotechnics.

The prepared materials are fully dense composites with unique properties, combining high-density energy with extremely high reactivity. Typically, two or more starting materials are combined. As they're milled, smaller and smaller particles of the harder component get embedded into a matrix formed by the softer component. Dreizin likens the structure of the prepared powder particles to raisin bread, but the harder components (the raisins) have nanometer dimensions, while the entire particles are larger, with sizes ranging from 1-100 microns.

"These materials have higher heats of combustion than conventional hydrocarbon fuels and other energetic compounds. However, they typically have longer ignition delays and lower burn rates than organic energetic materials," he explains. "The benchmark is energetic metals like aluminum and boron." One gram of boron, for example, packs as much energy as five grams of RDX or four grams of TNT.

Applications range from metastable alloys that serve as biocidal agents to neutralize anthrax, for example, to propulsion for both large space exploration ships and for smaller devices capable of carrying larger payloads than is now possible.

There are also entirely new uses as well, which he describes as dual purpose. In one example, both an energetic material, such as an explosive or a biocidal agent, and the case that encloses it would be composed of these metastable compounds.

"The idea would be to dispense with a structured material, such as a steel case," he explains, adding that the protective coating would only allow the material inside to combust when activated.

Milling, an ancient technique, offers a simple, scalable and controllable technology capable of mixing reactive components on the nanoscale. Milling stops when the powders have reached a metastable phase to create a variety of inorganic reactive materials, including nanocomposite thermite, metal-metalloids and intermetallic systems.

Different protocols, such as milling at cryogenic temperatures, are used to prepare hybrid reactive materials with various components mixed on different scales.

Using sophisticated new methods, Dreizin and his colleagues prepared a metal-halogen composite with a metal matrix that stabilizes the halogen at temperatures substantially exceeding its boiling point. Without such stabilization, halogen, a biocide packed inside the materials, is difficult to handle, as is its controlled release. The new materials can be safely stored and handled retaining the halogens, which would be released only when the material is ignited.

But milling poses challenges, because the novel energetic materials are easily ignited by impact or friction. In addition to synthesizing new compounds, his lab conducts customized ignition and combustion experiments to test and characterize ignition delays, burn rates and flame temperatures for the prepared materials in different oxidizing environments.

"Most of the new materials designed in our lab are nanocomposite powders prepared using mechanical milling of readily available powders of metals, such as aluminum, magnesium, titanium and others, metalloids such as boron, and metal oxides. Thermal analysis is used extensively to characterize reactions occurring in the prepared materials upon their heating," he says, adding that he uses common materials-characterization techniques, such as X-ray diffraction and electron microscopy, as well.

Designing a Potent Counter-Terrorism Tool

In some scientific circles, the metal boron is viewed as an underachiever. Best known for its role in the household cleaning compound borax, boron is also touted by engineers as a potential energy source capable of generating more heat than gasoline or jet fuel. The challenge to date, however, has been to harness its latent power.

"Boron is the most energetic metal, with the highest energy per gram. It has the potential to be used as an additive in missile propellants and explosives, and in compounds that release chemicals to destroy biological weapons. But it combusts slowly and takes a long time to ignite," notes KERRI-LEE CHINTERSINGH-DINNALL, a Ph.D. student in chemical engineering who is exploring methods to make boron burn faster and more easily.

She recently received a vote of confidence. At a meeting held by the U.S. Defense Threat Reduction Agency to review ongoing research on materials capable of defeating or disabling weapons such as anthrax, Chintersingh-Dinnall won the poster competition for her work in the lab adding iron to boron by a method called ball-milling to accelerate its combustion. Later, she presented her work on boron doping at the American Institute of Chemical Engineers Annual Meeting and Materials Research Symposium.

She is currently working on different techniques to incorporate other metals with boron and add pressure to the combustion chamber to see if that, too, speeds up the process.

"Our results are promising. We found that pretreating boron with solvents such as acetonitrile improves ignition and adding iron speeds up boron burning in air and steam," she says, noting of boron's potential, "It's mined here in the U.S., it's cheap and it's a hard metal powder that can potentially deliver more energy in a smaller package than existing fuels. It's also environmentally safe to use. It's not toxic."

Scientists who focus on energetic materials have an enduring interest in boron's capacity. When it reacts with oxygen, its chemical bonds break and reform to produce boron oxide, releasing a third more energy for the same weight as diesel fuel, for example. The trick is to make it burn fast enough that it becomes practical to use.

Chintersingh-Dinnall says her research on boron is sparked by "the current challenges the energy community faces" and by her longstanding interest, dating back to her undergraduate years in Jamaica, in alternatives to fossil fuels, such as castor oil and wastewater algae. Boron intrigues her in particular because of its potential use in many applications.

In the World of Nanomaterials, the Carbon Nanotube Is King

Somenath Mitra, a chemist and environmental scientist, says he was first intrigued by carbon nanotubes more than two decades ago, upon discovering their unique absorbent properties.

"Unlike other forms of carbon, such as charcoal, carbon nanotubes lack pores. Molecules cannot pass in and out of them, creating resistance, but rather sit on the fibers' very high surface area, from which they are also easily retrieved," explains Mitra, director of NJIT's Otto H. York Center for Environmental Engineering and Science. "With other materials, we can lose molecules in these cellular 'caves.' But with nanotubes, the minute you heat them, they're back."

Somenath Mitra, distinguished professor of chemistry and environmental science, was recently awarded a patent for a water desalination and purification technology that uses carbon nanotubes to remove salt and pollutants such as volatile organic compounds from brackish water and industrial effluent so that it can be reused by businesses and households.

Recently, he's been using carbon nanotubes in water purification. One of their key characteristics is the capacity to rapidly absorb both water vapor and industrial contaminants, including volatile organic compounds (VOCs), and then quickly release them.

Mitra was recently awarded a patent for a water desalination and purification technology that uses carbon nanotubes to remove salt and pollutants such as VOCs – chemicals routinely used in solvents – from brackish water and industrial effluent so that they can be reused by businesses and households. His new carbon nanotube immobilized membrane is designed to filter higher concentrations of salt than is currently feasible through reverse osmosis, one of the standard industry processes. The distillation process runs on energy-efficient fuels such as waste heat, low pressure steam and solar energy.

"There is a huge and growing demand for potable water coming from developing nations that are modernizing their infrastructure to improve living conditions. At the same time, droughts caused by climate change are reducing supply in many regions of the world, including parts of the U.S.," notes Mitra. "Our hope is to expand the supply of water in places that really need it, while also reducing costs for industry."

Besides filtration, these versatile fibers are also used widely in electronics, polymers, composites, solar cells and batteries. An atom thick and about 10,000 times smaller than a human hair in diameter, they are very good conductors and extremely strong. "By putting them in epoxies and polymers, for example, we can imbue these materials with those properties," he says.

His work in the area of microwave-induced carbon nanotube purification and functionalization has wide-ranging applications in several of these sectors, from batteries to thin films.

"Nanotubes are useful in batteries, where the charge has to move, because they facilitate electron mobility in the electrode, while also making batteries stronger and more durable," explains Mitra, who has developed flexible batteries for several potential applications.

"If we're going to have bendable electronic devices that we can put in cellphones, biomedical devices such as sensor patches, and even on clothing for soldiers, for example, then we also need to have bendable batteries," he says. "Batteries and solar cells using carbon nanotube composites can be painted on flexible substrates with an inkjet or other type of printer."

In other research, Mitra has developed sensors for use in the continuous monitoring of organic contaminants in air and water, and devices to purify water. He has, for example, developed a variety of air monitoring techniques for parts-per-billion-level measurements in ambient air and industrial smokestacks. Even in this sector, he notes, "Some of these devices, including monitors for greenhouse gases and VOCs, incorporate carbon nanotubes."

As Their Production Proliferates, a Pioneer in the Field Explores the Question: Are Carbon Nanotubes Safe?

A pioneer in the use of carbon nanotubes, environmental scientist and chemist SOMENATH MITRA is also one of the first researchers to study their impact on biological life as they become more widespread in the world around us.

These tiny carbon fibers are used in consumer products ranging from cellphones, to golf balls, to medicines, to airplanes. Going forward, they are viewed as key to technological progress on several fronts, including the development of batteries, fuel cells and an array of materials that are both incredibly strong, and yet extremely lightweight.

But while the minute size of carbon nanotubes is the key to their utility in diverse applications, it may also present an environmental and health risk. Such nanomaterials can be absorbed from the environment as air or water pollutants and migrate throughout the body and infiltrate diverse types of tissues. There is some concern that the hair-like nanoparticles could pose a threat similar to that of asbestos.

With a $2.5 million, five-year grant from the National Institute of Environmental Health Sciences, a division of the National Institutes of Health, Mitra and collaborators, including ANDRIJ HOLIAN, director of the Center for Environmental Health Sciences at the University of Montana, are conducting toxicity studies focusing on the lung.

"Determining which characteristics and properties of carbon nanotubes could cause human health effects is essential for improving our understanding of these materials, as well as for developing safe applications. This is the overall objective of our effort," says Mitra, noting that nanotube behavior and potential toxicity depend on a variety of parameters, including length, diameter, functionality and the kinds of materials that are attached to them. Mitra is making nanotubes with a variety of characteristics and properties, including the ability to disperse in water and biological fluids – or not. Holian is testing these different versions in animals.

"At this point, we don't know a lot. We don't know, for example, what happens if they're inhaled or consumed in a drink or what the impacts of chronic exposure might be," Mitra says. "Carbon nanotubes are one of the most commercially viable nanomaterials we use, and yet we don't have the technology to detect, measure or remove them from the environment."

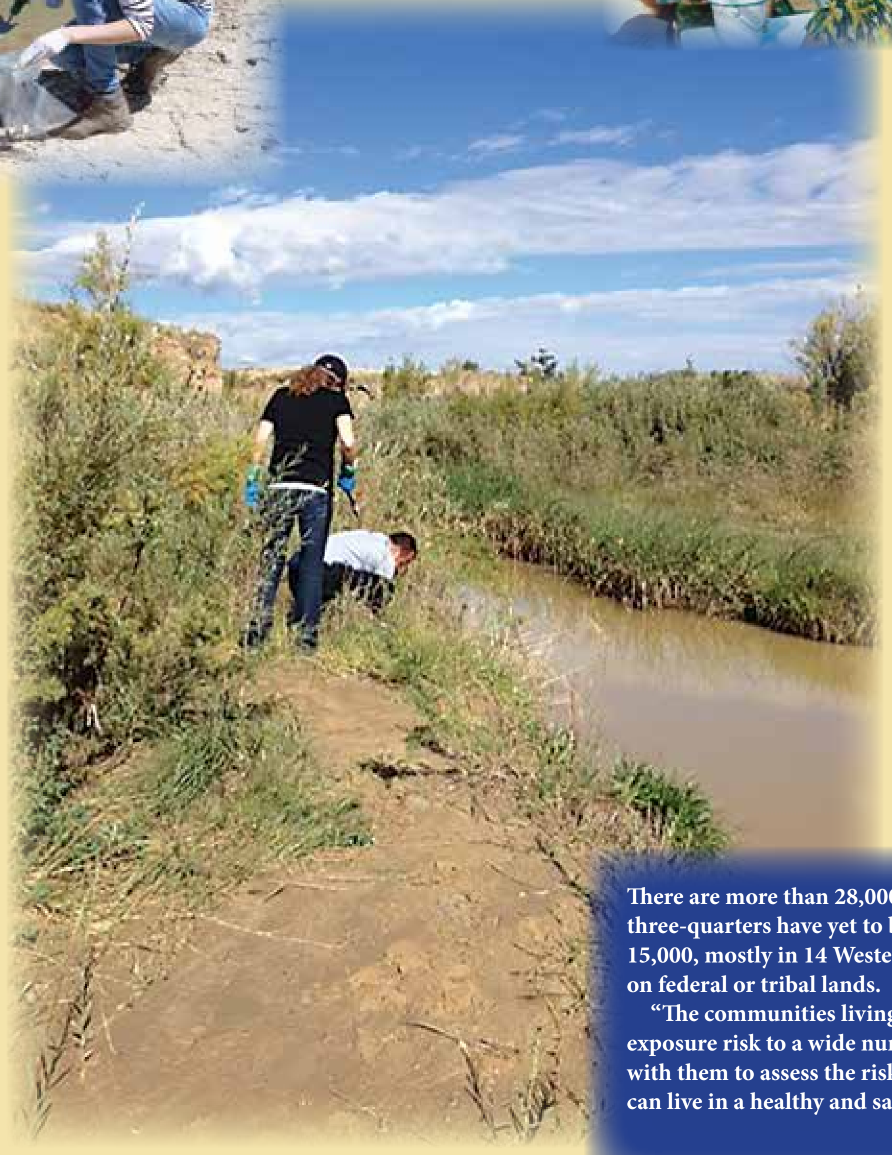
Mitra, an expert in environmental monitoring who has developed methods to take trace measurements of chemical compounds, says the issue goes far beyond this one material.

NJIT and other research universities set protocols for experiments involving structures with at least one dimension less than 100 nanometers and those that create or use materials with unique properties and functions because of their nanometer scale.

Once they enter the environment in products, however, "there is currently little regulation of nanomaterials," Mitra says. "We can use them to do good things, such as incorporating them in plastic sheets that provide protection from electromagnetic waves, but once they are discarded, burned and enter the atmosphere, they can be highly dispersible. In some cases, they can dissolve in water like sugar and are very difficult to remove."

Reversing Mining's Toxic Legacy on Tribal Lands

Lucia Rodriguez-Freire develops wastewater treatment systems that remove persistent contaminants using ubiquitous, inexpensive materials, while optimizing bioremediation strategies for metal-contaminated natural environments.



When a federal inspection team inadvertently released three million gallons of heavy metal-laden waste from a century-old, defunct gold mine near Silverton, Colorado, into the Animas River, **Lucia Rodriguez-Freire** was one of the first responders on the scene.

"We knew we needed to react immediately: to analyze the metal content in the water and sediments, and assess the movement of contaminants from the mine to downstream in the river," Rodriguez-Freire, an assistant professor of civil and environmental engineering, said of the 2015 spill, which famously turned the Animas gold, while posing ongoing risks for the farming communities in the Four Corners region, which include Navajo, Jicarilla-Apache, Southern Ute, Ute Mountain Ute and Hopi tribes.

Among other findings, her team detected elevated concentrations of metals in the water after high-flow events. In looking to the sediment for clues, they found the mineral jarosite, which is known to precipitate – or combine into solids – with heavy metals, but remains stable only at acidic pH levels. As those levels rose during flow events, the heavy metals appeared to mobilize.

Rodriguez-Freire analyzes interactions between biological and inorganic systems, such as microorganisms and metals, to understand the effect of contaminants on natural biogeochemical cycles and to remediate polluted sites. She designed, for example, a novel process to extract and stabilize arsenic from contaminated water by forming arsenic minerals such as realgar and orpiment, using microorganisms from anaerobic sludge. In a bioreactor, the microorganisms together reduce arsenate and sulfate in the presence of ethanol in the arsenic minerals, removing more than 90 percent of the dissolved heavy metal from the solution.

Her goals are to develop state-of-the-art wastewater treatment systems that remove persistent contaminants using ubiquitous, inexpensive materials, and to optimize bioremediation strategies for metal-contaminated natural environments.

She describes her approach to environmental remediation as a restoration of a natural system's equilibrium – an alternative approach to removal.

"At mining sites, the metals that end up contaminating water and sediment were always there, but human activity disrupts the natural equilibrium through the use of leaching chemicals, direct alteration of the ecosystem and increased erosion. In hard rock mines in the Southwest, such as the Iron King Mine in Arizona, the Jackpile Mine in New Mexico, and the Gold King Mine in Colorado, you can see perfect examples of systems that were once in equilibrium when the rock system was intact. Heavy metal concentrations in the area were high before mining occurred – which brought the miners there. They then left a toxic legacy from open-pit mining of mine waste accumulation in mine tailings and acid rock drainage," she notes. "The challenge is to restore the natural equilibrium of the mine site, by slowing down the processes that lead to the mobilization and movement of contaminants."

Rodriguez-Freire also studies the ways that uranium and arsenic accumulate in plants used by Native American communities living near abandoned mines.

"We want to understand the way contaminants interact with soil and water, microorganisms and plants, and look for mechanisms to stabilize them," she notes.

While organic contaminants can be degraded into more innocuous components, metals such as lead, cadmium, arsenic and uranium are persistent. But they can be stabilized to prevent their movement and contact with people. At the Jackpile Mine site, where local plants accumulate uranium in their roots, Rodriguez-Freire and her colleagues are investigating how ubiquitous microorganisms and soil amendments can be deployed to prevent the toxic metal from moving.

"As we observed with arsenic, we can promote changes in metal speciation to a less mobile, more stable phase by adding nutrients to stimulate microbial activity. The target metal specie will become a more stable solid, or it will be more strongly adsorbed into the soil sediments. In this way, we are removing the contaminant from the water and into the sediment, trying to restore the original equilibrium of the site," she says. "For this work, we need to use an integrative approach, working with microbiologists, geologists and chemists for a holistic understanding of the mechanisms of transformation."

There are more than 28,000 abandoned mines in the U.S., of which three-quarters have yet to be investigated or remediated. Of these, 15,000, mostly in 14 Western states, involve uranium. Most of them are on federal or tribal lands.

"The communities living near the abandoned mines are at higher exposure risk to a wide number of contaminants, and we need to work with them to assess the risks and to restore the polluted sites so they can live in a healthy and safe environment on their lands."

- Lucia Rodriguez-Freire

Harnessing the Earth's Own Heat

There is a potentially limitless supply of renewable, carbon-free energy within the Earth's crust if we could only permeate the thick layers of crystalline rock that sit over it, barring access. So far, success in harnessing the Earth's own heat has been mostly limited to tapping the boiling hot water that bubbles up with little prompting close to the surface.

"The main challenge is to tap into deeper and less fractured hot rocks. This would make geothermal energy accessible in many more locations across the world. In order to achieve this goal, we need to fracture the rock in order to increase its permeability," says BRUNO GONCALVES DA SILVA, an assistant professor of civil and environmental engineering who, as a doctoral student at MIT, worked with a team of researchers who contend the U.S. alone could produce 100,000 megawatts of power within the next 50 years from what is called enhanced geothermal systems.

To access the Earth's heat, cold water is injected through a well into a hydraulically fractured rock formation at a temperature of more than 200 degrees Celsius, usually at depths of more than two kilometers below the surface; the heated water is then recovered at the surface through another well, where it is used to produce electricity or heat.

But engineers must first figure out how to create networks of interconnected fractures that will increase the permeability of the crystalline rock without creating major earthquakes during the hydraulic fracturing operations. With funding from the National Science Foundation, Goncalves da Silva is building a device to study in the laboratory the fracturing processes under real-world field stress conditions. It will allow him to independently apply stresses in three directions (one vertical and two horizontal) and to simultaneously monitor the fracturing visually and through acoustic emissions.

The acoustic emission events, or microseismic events, are monitored through eight sensors. They capture the small earthquakes that are produced when fractures develop. On one hand, these microearthquakes are important to understand the location and types of fractures that are produced; on the other hand, these events can't be too large, as they can cause damage at the surface to field applications. "The goal is, therefore, to produce hydraulic fractures in an efficient way without causing major earthquakes," he notes.

The same hydraulic fracturing methods could also be applied to artificially enhance the recharge of wells at shallow depths. "This may be particularly useful to increase the supply of clean water to populations in dry regions," Goncalves da Silva notes.

Detecting Diseases Before They're Deadly

Eon Soo Lee (middle and below) and his team are developing a nanotechnology-enhanced biochip that would give doctors and patients in a range of health care settings the ability to detect deadly diseases such as ovarian cancer and pneumonia early in their progression.

Eon Soo Lee is developing a nanotechnology-enhanced biochip that would give doctors and patients in a range of health care settings the ability to detect deadly diseases such as ovarian cancer and pneumonia early in their progression.

The device includes a microfluidic channel through which a tiny amount of drawn blood flows past a "sensing platform" coated with biological agents that bind with antigens – biomarkers of disease that elicit an immune response by the body – triggering an electrical nanocircuit that signals their presence.

The chip's biosensors are "highly sensitive to small amounts of very specific antigens," explains Lee, an assistant professor of mechanical engineering, who added that a single biochip's platform could potentially include sensors for several diseases, from cancers to viral infections.

The technology is being designed for use by specialists and primary care doctors and, Lee hopes, health care workers in remote clinics in developing countries who can administer the tests with a simple finger prick.

He has won federal backing from the National Science Foundation's I-Corps program to commercialize the device, as well as encouragement from venture capitalists in the state, including the New Jersey Health Foundation (NJHF), which awarded him a $50,000 Innovation Grant.

"As we know, early detection can improve treatment outcomes for patients significantly," says George F. Heinrich, M.D., vice chair and CEO of NJHF, a not-for-profit corporation that supports biomedical research and health-related education programs in New Jersey. "Currently, doctors rely on diagnostic devices requiring a minimum of four hours of sample preparation through centralized diagnostic centers rather than their local offices. We are interested in Dr. Lee's project because the biochip he is developing would provide instant results at a local office or point of care without needing sample preparation."

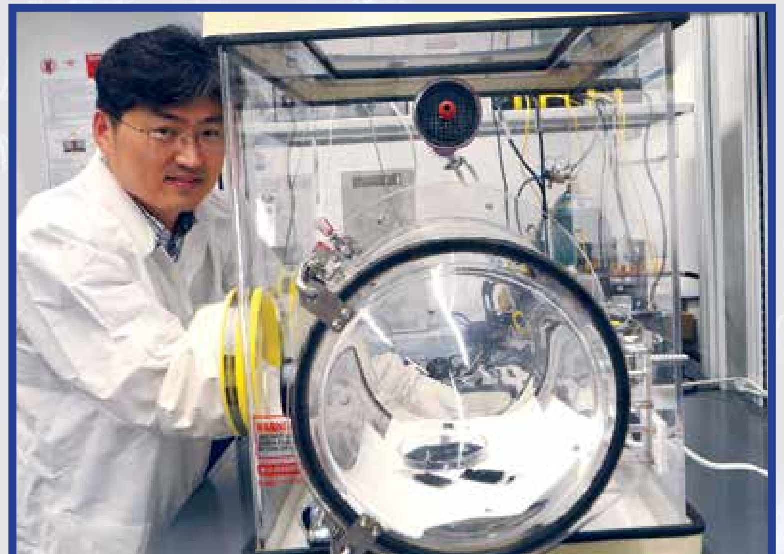
If successful, the biochip will expedite the diagnosis of diseases including viral infections such as HIV, sexually transmitted diseases and toxoplasmosis, and cancers such as prostate, liver and thyroid cancer.

Lee is now working with oncologists at Hackensack University Medical Center who care for women with ovarian cancer – often undetectable until it has reached a late stage that is difficult to treat – to develop and test the technology.

"Screenings for ovarian cancer are often cumbersome and uncomfortable," he notes.

The biochip is designed to reduce the possibility of sample contamination by minimizing the need for flow control devices and connecting tubes. It analyzes a tiny amount of blood within two minutes without any external devices.

One of the device's core innovations is the ability to separate blood plasma from whole blood in its microfluidic channels.



Blood plasma carries the disease biomarkers and it is therefore necessary to separate it to reduce detection "noise" in order to achieve a highly accurate test, Lee explains.

In addition to Hackensack University Medical Center, collaborators include researchers at Rutgers New Jersey Medical School and Brookhaven National Laboratory's Center for Functional Nanomaterials.

"The partnership and support from the New Jersey Health Foundation is a critical component of our efforts to advance commercialization of early-stage life science technologies," says Judith Sheft, associate vice president for technology development, who notes that Lee had previously won funding for his research from the National Science Foundation I-Corps program as an NJIT site team before winning a grant from the agency's national program.

Lee, who directs NJIT's Advanced Energy Systems and Microdevices Laboratory, has a background in micro- and nanochannel fabrication, flow characterization and nanomaterial implementation, and develops fuel cell and energy technology, in addition to biomedical devices. His lab focuses on the non-platinum group of metal (non-PGM) catalysts to replace PGM catalysts for electrochemical-energy systems such as fuel cells and batteries, and industrial applications such as filtering systems and petroleum-processing systems.

Principal research includes synthesizing and characterizing innovative high-performance new non-PGM catalysts from carbon materials such as graphene, and understanding the fundamental mechanisms of the reaction.

New Henry J. and Erna D. Leir Research Institute to Focus on Global Threats to Business and Industry

From stock market crashes to climate change, global disruptions pose substantial threats to corporate sustainability. To mitigate risks to their economic security, environmental accountability and social responsibility, companies must be able to identify their vulnerabilities and keep closer tabs on potentially volatile conditions around the world.

New cognitive business and machine learning methodologies, designed to help companies collect, visualize and analyze data from wide-ranging sources, are viewed as central to these efforts.

"All across the value chain, companies have to know their vulnerabilities and prepare for risks on many fronts, not just from market gyrations," explains REGGIE CAUDILL, dean of NJIT's Martin Tuchman School of Management (MTSM). "We can use these new analytic tools to evaluate potential weaknesses and even predict events, which will put us in a better position to manage business continuity and remain agile and resilient."

With a five-year, $1.5 million grant from The Leir Charitable Foundations, NJIT will develop these business data science tools. The university's newly launched HENRY J. AND ERNA D. LEIR RESEARCH INSTITUTE FOR BUSINESS, TECHNOLOGY, AND SOCIETY will have a dual mission: to conduct business and management research and to establish partnerships with academic and business communities, regional economic leaders and government agencies.

For the business and management research part of its mission, the new Leir Research Institute will develop predictive and proactive data analytics embedded within cognitive business and management tools. Caudill points to the sudden scarcity of valuable natural resources, such as lithium or rare earth metals, to exemplify an unforeseen disruptive event. Critically important to the technology industry, these metals are produced only by a few mines globally, and some of these are in countries whose diplomatic relationship to the U.S. can be strained, making a critical shortage a distinct possibility.

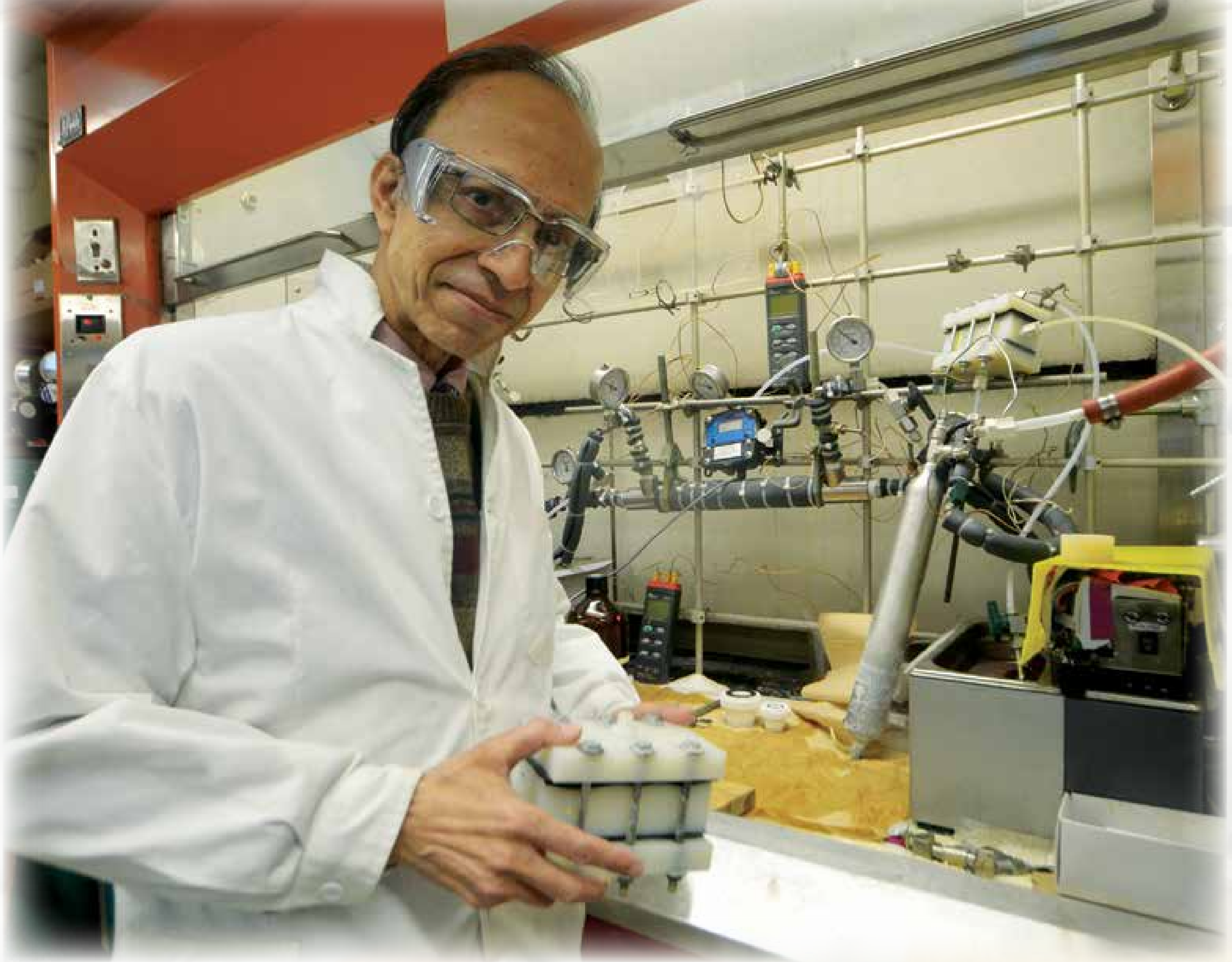
"You can imagine the impact to the electronics sector," Caudill notes. "But if we can do sufficient text mining and natural language processing of social media and get a handle on the potential for disruption, the earlier we will know. Companies can then respond with appropriate actions, including identifying new sources to ensure continuous supply."

In establishing partnerships among various communities, the Leir Research Institute will also develop metrics to help companies measure their own sustainability. "This will allow companies to see where they need to prioritize investments," Caudill says. Other institute initiatives include creating tools to help companies integrate disparate business data sets and providing insights into business data analytics through machine learning and AI methodologies.

The Leir Charitable Foundations grant will also support annual research symposia and Henry J. and Erna D. Leir Fellowships for graduate students and distinguished faculty. The fellowships, in particular, will aid in recruiting candidates for MTSM's new Ph.D. program in business data science, one of the first in the country to integrate business analytics and management systems theory with statistics, computing science and engineering.

"The overarching goal of The Leir Research Institute will be to transfer scholarly outcomes and research innovation into everyday business practice and industrial operations, so that business and industry can move beyond just being competitive in the marketplace to creating real shareholder and social value by becoming eco-efficient, resilient and sustainable," Caudill summarizes. "Climate change is having a real impact on business operations. Fortunately, companies are becoming much more cognizant about sustainability. It's on their radar screen."

Nanofilters Are Changing the Landscape of Chemical Engineering



With 35 patents and counting, Kamalesh Sirkar, a pioneer in membrane technology, develops devices to separate and purify air, water, industrial streams, solvents, pharmaceuticals, cells and nanoparticles. His latest invention converts brines with high salt concentrations into potable water.

Kamalesh Sirkar, a pioneer in membrane technology, takes a sector-spanning, multitasking, omnicurious approach to his research. With 35 patents and counting, he develops devices to separate and purify air, water, industrial streams, solvents, pharmaceuticals, cells and nanoparticles.

The applications are wide-ranging: masks that allow water vapor in, but keep toxic chemicals out; thin polymer pill coatings that release medications at a controlled rate; and ultrathin films able to separate and capture a variety of gases, such as carbon dioxide, from power plant smokestacks.

"The common theme is that all of these membranes separate, purify or block – or rather, they allow some species to pass through, while blocking others," he says. "But each type of membrane is different, depending on what is being blocked and what is allowed to pass through."

More recently, he has developed a novel membrane distillation technology capable of converting sea and brackish water into potable water with a considerably higher water recovery rate than the standard method, reverse osmosis. Using porous hydrophobic hollow fiber membranes with porous coatings of fluorosiloxane on their outside surface, he has been able to treat brines with salt concentrations going up to around 20 percent.

This technology, which can handle salts at various concentrations, has been used successfully to treat sea water collected near the discharge from a nuclear power plant and polluted by high levels of scaling salts.

In the distillation process, water vapor evaporated from hot brine on one side of a porous hydrophobic membrane diffuses through the nonwetted pores of the membrane to the other side, where it is condensed by flowing cold distillate water. The design of the hollow fiber membrane device is such that there are numerous spontaneous circulating eddies continuously scrubbing the surface of the hollow fiber membrane, which is designed also to reduce fouling.

Membrane distillation is advanced technologically on several fronts. It can utilize waste heat from a variety of sources, prevent thermal pollution and operate at essentially atmospheric pressure.

"Although further developments are taking place, we believe we are ready to go large-scale with these," Sirkar says.

In his lab, the Center for Membrane Technologies, he is currently investigating three problems: solvent-resistant nanofiltration with pharmaceutical applications; the separation of solvent mixtures by a membrane; and the development of highly selective ultrathin membranes for use in a variety of separations.

"The organic synthesis of drugs involves many steps requiring frequent exchanges of solvents, the recovery of catalysts and the concentration of active pharmaceutical ingredients," he notes. Nanofiltration membranes capable of resisting solvents are of great value for such operations, as they allow solvents to pass through while retaining solutes with larger molecular weights.

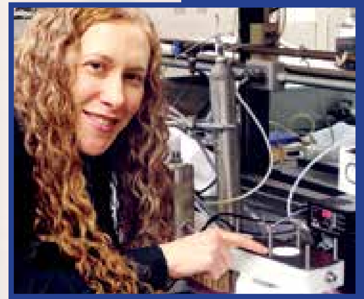
"We are studying the behavior of novel, inert polymeric membranes for nanofiltration that permit solvent flow, but reject the solutes," he says. "In related work, we're investigating the possibility of separating organic solvent mixtures with membranes."

"Successful membranes and membrane processes allow beneficial interactions between selected species and fluid streams with membranes and develop nonbeneficial interactions with others," says Sirkar, who won the 2017 Alan S. Michaels Award for Innovation in Membrane Science and Technology from the North American Membrane Society. Colleagues describe his co-edited Membrane Handbook, first published in 1992, reissued in 2001 and still in print, as a "must-have book for membranologists."

Sirkar is best known for developing the concept of membrane contactors, a process that permits two phases that do not mix, such as two liquids or a liquid and a gas, to contact each other at the pores of a membrane – without dispersing into each other – in order to introduce or extract specific compounds across it. The technology is used, for example, to introduce carbon dioxide into beverages, to produce concentrations of oxygen at much less than 1 part per billion in ultrapure water needed for semiconductor production, and to extract valuable pharmaceuticals in aqueous-organic extraction systems, among other separation or purification processes.

"Classical chemical engineering devices and techniques are large, energy-intensive and demanding to operate and scale up. Membrane-based devices are often an order of magnitude smaller, easy to scale up and operate, and often consume less energy," Sirkar says, adding, "These technologies present opportunities to significantly change the landscape of chemical engineering, and that is what continues to excite me about this field. There are so many problems to solve."

A Mathematician Takes Aim at Gunk



Some industrial processes seem to resist optimization. Filters impervious to the slings and arrows of accumulated "gunk" – the particles, minerals and organic buildup that foul water treatment facilities, nuclear power plants and even breweries – are prime among them.

And that's where the mathematicians come in.

"Several of my colleagues at NJIT are designing new membrane technologies. I focus on how membrane filters foul up," says LINDA CUMMINGS, a professor of applied mathematics. "The goal is to design a membrane microstructure that will maximize a filter's lifetime and minimize the cost of maintaining it."

She looks in particular at ways to optimize the size, shape and distribution of pores within the membrane. "They need to be big enough that the pressure required to force the filtrate through the membrane is not too high, but not so big they don't filter out the gunk."

As well as the internal structure of the membrane, fouling depends on factors such as the flow dynamics of the feed solution, and the shape, size and chemistry of particles in the feed. "But the broad engineering challenge is the same: to achieve finely controlled separation at low power consumption."

So far, her team has determined that the internal patterning of pores within the membrane, and the connections between them, are important. In particular, they can predict how pore size and connectivity should vary across the membrane in the direction of flow in order to maximize the filter lifetime – since fouling begins at the upstream surface, pores there foul fastest, so they need to be larger than those downstream, for example.

Cummings first took up membrane modeling at a "Mathematical Problems in Industry" workshop funded by the National Science Foundation (NSF) that annually brings together academics and representatives from industry to tackle longstanding industrial problems in fluid mechanics, data analysis and mathematical finance, among other areas.

"The industrial problems are presented on Monday, and the academics then break up into groups to work intensively on them for three days. On Friday, we report our progress," says Cummings, who has led three of these workshops at NJIT since 2011. "In this case, the progress we made was sufficiently promising that NSF awarded further funding to take a deeper look."

Camelia Prodan's Curiosity Shop of Energy-Bending Experiments

1. Research assistant Kai Qian M.S. '17 positions sensors (guitar pickups) to measure the resonance from the mechanical spinners arranged on the lab's two-dimensional model. At specific frequencies, all the vibrational energy is directed to the edge of the model. This is a direct result of the patterning of the structure. **2.** Postdoctoral researcher David Apigo (left) and Qian (right), who both play the electric guitar, pluck the instruments that inspired them to use pickups as sensors. "Pickups, which capture vibrations and convert them to electric signals via magnetic induction, detect the signals from the spinners as they resonate, similar to guitar strings," Apigo explains. **3.** The Prodan research team holds a one-dimensional model made of mechanical spinners that, when shaken, will localize energy at the model's edge. The model is considered 1D because it propagates energy in one direction. **4.** The team uses an inverted microscope to study the vibrational properties of microtubules, the skeletal material in eukaryotic cells. Prodan is interested in how microtubules store energy at their edge.

With its wild assortment of tubular, mysteriously patterned and multisided objects stashed on tables and shelves and hanging from beams, physicist **Camelia Prodan's** lab looks like a curiosity shop full of toys for scientists. There is a long black tube that swallows sound, what looks like a Newton's cradle that extends for 8 feet overhead, a pentagonal box with a honeycomb lattice interior, fidget spinners with magnets and more.

What these disparate objects share is that each manipulates energy waves through its physical patterning, either blocking, channeling or dissipating them.

Prodan, the director of the Keck Center for Topological Dynamics, is researching topological phonon edge modes – quanta of sound or vibrational energy confined to the edge or surface of a material – that likely play a key role in the functioning of cellular microtubules, the skeletal material in eukaryotic cells.

"Our theoretical evidence suggests that topological phonons are integral to the function of microtubules, which continuously disassemble at a fast pace within the cell. During cell division, for example, the motion of the chromosomes relies heavily on that of the microtubules and would not occur without it," she says. "We hypothesize that topological phonons are responsible for containing the energy that triggers the initial disassembly. Many cancer drugs attach to microtubules to halt their movement, thus preventing cell division."

Inspired by these natural phenomena, Prodan is laying the theoretical and experimental foundation for a new class of engineered materials that exhibit unique vibrational and thermal properties found in phonon edges.

"We are engineering materials to direct or carry energy – electric, electromagnetic and mechanical – with almost no dissipation," she says. "The surfaces of these materials, determined by their internal patterning, are also tamper-proof. If an area is damaged, the injury does not alter the properties of the remaining material, in the same way that a magnet cut in half will re-establish polarities at the ends of each new piece.

"What is so novel about them is that historically we've made extraordinary materials such as superconductors only under extreme conditions, like very low temperatures, but we believe we can make these under normal conditions."

A material's pattern can also prevent permeation by energy waves by redirecting and dissipating them, by allowing them to enter through different portals and intersect in such a way that they cancel each other out, for example.

The potential applications are tantalizing: more efficient ways to store energy; the ability to passively focus and amplify sound, as a laser does light, for hearing devices, for example, or to deaden it; the construction of lightweight insulated clothes and bullet-proof vests; and the management of heat flow around structures in small devices and large building elements.

With a $1 million award from the W.M. Keck Foundation, Prodan is hoping to apply these discoveries to cancer therapy research.

"The hypothesis is that chemotherapy drugs, such as Taxol, change or remove entirely the topological phonons from microtubules in order to prevent cells from dividing. In neurodegenerative diseases, however, the microtubules must be stable and not disassemble, as their disintegration prevents neurons from communicating with one another.

"I believe we can propagate energy waves without loss through patterning at any scale," she says. "The pattern is what's important, not the material it's made of."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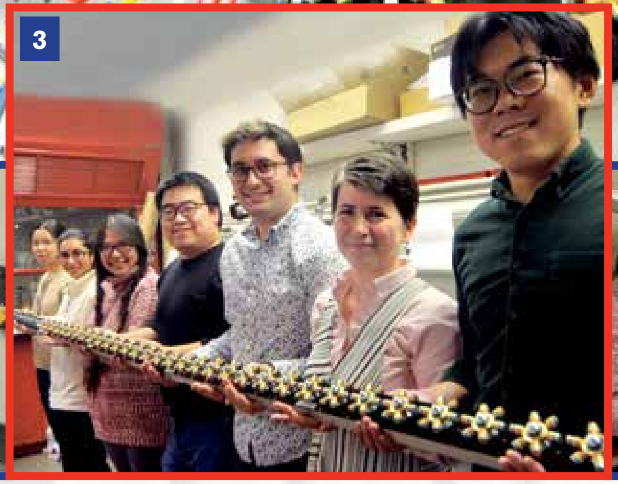
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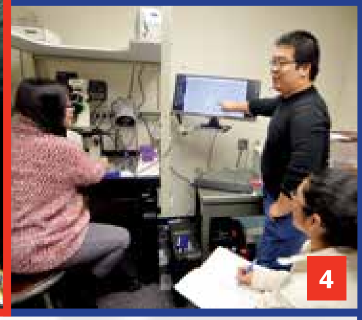
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Redirecting Sound to Improve Hearing Aids

Hearing aids nestle around the ear, amplifying sounds with tiny microphones. Little has changed in their placement over the past 20 years; they typically sit behind the ear or on top of the pinna, the ear's outer structure. For many wearers, it is frustratingly difficult to pinpoint the direction of speakers, even if close by.

"Microphone placement directly influences both signal quality and the precision of spatial auditory cues, and yet we still don't know the best place to position them," notes ANTJE IHLEFELD, director of NJIT's Laboratory for Neural Engineering of Speech and Hearing (right), adding, "Ear shapes also vary from person to person."

Ihlefeld has teamed up with CAMELIA PRODAN, a physicist (left), to explore technologies to better predict the movement of sound and to optimize devices accordingly for individuals. They are designing and 3D printing ears of different anatomical configurations and placing tiny microphones inside to see how sound propagates around the ear.

They are modeling the acoustic properties of the pinna as a Fibonacci spiral, a pattern commonly found in nature, from nautilus shells to galaxy configurations, which widens without changing shape. They will examine how the resulting properties relate to auditory function. Preliminary data from Prodan's lab show that Fibonacci channels concentrate energy waves such as sound at their edges, a property known as a topological edge mode. She and Ihlefeld are investigating if pinnae are topological materials as well.

Ihlefeld and Prodan hope to develop their approach into an algorithm for predicting the perceived spatial properties of sound reaching the eardrums based on the shape of an individual's ear, with applications ranging from hearing aids and cochlear implants to virtual reality auditory displays and biomimetic sound recording devices.

Prodan wonders if it's possible to concentrate sound as a laser does light. "Sound goes everywhere, but we're hoping to design new materials for sound propagation."

Ihlefeld, who works with populations of cochlear implant users to explore central nervous system function under hearing loss, adds, "It would be very helpful to be able to channel sound through the ear so that people hear optimally even in situations with background sound."

Hunting for New Materials to Convert Sunlight Into Energy

The term "alternative energy" calls to mind prominent installations such as roaring wind turbines and solar panels stretching across sunbaked planes. But the search for new forms of power production is taking place just as urgently at the level of materials science.

At NJIT, **Trevor Tyson**, a physicist, is collaborating with **Yong Yan**, a chemist, to study a promising category of crystals called halide perovskites that convert light into electricity.

"In principle, what's on your roof – silicon-based panels – is very expensive, so we're looking for alternatives," says Tyson, distinguished professor of physics, who called research on perovskites, which are made from organic ions, lead and halides (chlorine, bromine or iodine), still at an early, if intriguing stage. "Ideally, these new materials could be spin-coated at low temperatures with a simple method."

While the crystals easily produce electricity, even when they contain defects, they also fall apart when exposed to water – and contain lead.

"So as currently configured, they would be useless in a photovoltaic panel. What we're trying to determine is if we can find an analog that would be benign, stable and easy to process," he says, adding, "In general, we find systems in nature that can be enhanced with new components in the laboratory. In some cases, we're mixing organic and inorganic elements."

Yan synthesizes the crystals in his lab and Tyson analyzes them with a broad range of unique tools at NJIT and Brookhaven National Laboratory. This work builds on the extensive experience gained by Tyson's group on complex oxide perovskite systems aimed at improving materials for data storage both in sensors and storage media.

"Across all of our materials studies, we're trying to determine how structure – at the atomic, nano- and microlevels – affects properties. We study these materials in a vacuum environment and subject them to a variety of forces to see how they respond. In the case of perovskites, we're trying to figure out what causes them to decompose in the real world and determine how to replace components to make them more stable," says Tyson.

Trevor Tyson studies hybrid perovskites, among other complex materials, at multiple beamline workstations at Brookhaven's National Synchrotron Light Source, a multiuser facility that allows scientists to study material properties from THz to the hard X-ray region of the electromagnetic spectrum.

Among his many instruments there, he uses synchrotron spectroscopy to probe atomic and electronic properties, from correlated electron systems, to catalysts, to active metal sites in protein molecules. His group has developed high-resolution X-ray emission spectrometers to examine the chemistry of metal atoms.

They have also designed a new detector system that will have at least a 50-fold increase in counting rate over existing commercial systems, while maintaining the high resolution required to suppress unwanted background radiation. The detector system will be coupled with the group's high field magnet systems to understand how electric polarization is coupled to magnetism. These latter studies will be central to developing coupled magnetic and ferroelectric storage media with high information densities and possibly new functionalities.

Liberating 21st Century Data Networks From 20th Century Power Production

One of the grand quests of 21st century computing is to liberate sluggish information networks from their dependence on electricity.

"We need to bring the rate of data analysis to the speed of light. We should be using photons instead of electrons to process information," says **Andrei Sirenko**, professor of physics, noting that people currently produce more than 2 quintillions of data bytes per day.

"We're talking about everything from pictures of adorable kittens to national security data, and this means that data processing speed is everything. Without it, we will never be able to find what's important."

Using photons to transport information from chip to chip confers another potential societal advantage – it would be a much greener process that operated independently from electrical power altogether.

But that leap will also require freeing computing from restrictions imposed by silicon-based technology. As Sirenko puts it, "We need to come up with something new. The main material we use for optical processing, silicon dioxide, is the same as window glass – a technology that is now thousands of years old."

In the hunt for new materials, he is exploring a class of magnetoelectric oxides with unusual properties, including groups of iron and manganese oxides. In particular, their electrical properties can be manipulated by magnetic fields and their magnetic properties influenced by voltage.

Light also moves through them in atypical ways: It propagates "non-reciprocally," meaning light entering from one direction may follow a different trajectory than if it entered from another. "This happens at the atomic scale," he notes.

He analyzes unique samples obtained through a collaboration with **Sang-Wook Cheong**, a materials scientist at Rutgers University. They are perfect single crystals, but usually have magnetic domains on a microscopic scale.

"We're looking for the best materials in this class for information processing. They need to be able to harness photons and manipulate light inexpensively and move it efficiently," says Sirenko, who is studying these materials with analytical instruments he built at a beamline station at Brookhaven National Laboratory.

At his beamline station at Brookhaven National Laboratory, Andrei Sirenko uses an ellipsometer, which shines synchrotron radiation on the material to analyze polarization of the reflected light, thus revealing unique material properties in the THz spectral range.

"We also put these materials in extreme conditions such as low temperatures and high pressure to see how they are affected and how new functionalities can be created."

His lab is inside Brookhaven's National Synchrotron Light Source, a multiuser facility that allows scientists to study material properties from THz to X-ray spectral ranges. This facility has the brightest source of light in the world, enabling materials study with nanoscale resolution through bright X-ray imaging and high-resolution energy analysis.

"Our new analytical instrument at the MET (magnetospectroscopy ellipsometry time-resolved) beamline will have a huge number of new capabilities – a larger sample chamber, for example, and a stronger magnetic field capability of up to 7 Tesla. It will be able to change the direction of a magnetic field and lower the sample temperature down to 5 Kelvins."

Five Years After Hurricane Sandy, New Jersey Is Bracing for the Next Megastorm

Deane Evans, director of NJIT's Center for Resilient Design, is helping municipalities develop power microgrids that will keep critical facilities up and running in a blackout.

With 12-foot tidal surges and 100-mile-an-hour gusts, Hurricane Sandy quenched power all along the Jersey Shore, snapping transmission lines, felling utility poles and submerging substations. The storm left 2.6 million people in the state without electricity. In coastal Neptune Township, many residents lived without heat or light for nearly two weeks.

"These types of extended power outages are not only inconvenient, they can be potentially life-threatening, particularly for vulnerable populations. They can sap revenue from local businesses and substantially impair a community's capacity to initiate a robust recovery," notes **Deane Evans**, director of NJIT's Center for Resilient Design.

Five years after Sandy, the center's architects and planners are helping New Jersey municipalities refashion their emergency plans in order to keep critical facilities up and running in a blackout. As part of a project for the New Jersey Department of Community Affairs, the center is working with towns like Neptune as they develop plans for community-based microgrids. Based on the lessons learned by towns across the state shut down by the storm, the center is creating a new online education and training platform that will guide them through the process.

A microgrid is a localized power grid that serves a small network of electricity users – typically buildings – within a small, clearly defined geographical area. Power is generated from distributed energy sources, such as combined heat and power systems or renewable energy, located within its boundaries. The system is designed to easily connect to or disconnect from the larger electrical grid so that it can operate in "grid-connected" mode during normal conditions or in "island" mode during power disruptions.

While microgrids have historically been developed for multi-building institutions such as universities, large hospital complexes or military bases, community microgrids deliver power to a cluster of independent facilities – often with multiple independent owners – to provide a range of essential services to the public during and after emergencies. Properly designed and implemented, they can provide significant cost and efficiency benefits to municipalities during "blue sky" conditions and, at the same time, significantly improve resilience during blackouts and other hazards.

NJIT's platform provides a series of online tutorials to demystify microgrids for mayors and their staffs while guiding them through key phases of planning and development: the formation of a plan; a technical feasibility analysis; financing and design; construction; and operation. The program also addresses decision-making at the local level in the early stages, and offers a series of expert webinars for officials interested in a deeper analysis of specific microgrid topics.

"Interest in community microgrids has exploded across the U.S., partly in reaction to events like Hurricane Sandy and partly in recognition of the risks inherent in an aging, highly centralized grid," says Evans. "And even though these systems are in the early stages of their evolution, New Jersey has jumped out early and is one of the leading states in the country in promoting and supporting them. Our job is to move this innovative approach to power production forward."

Neptune's proposed microgrid is especially ambitious, seeking to link 27 critical facilities, from hospitals and doctors' offices, to drugstores and supermarkets, to schools and municipal buildings, to water treatment and sewage plants. The grid would be powered with nearly 4 megawatts of electricity supplied by an existing combined heat and power (CHP) facility at the Jersey Shore University Medical Center and about four times that much capacity generated by new sources, including additional, co-located CHP together with roughly 5 megawatts of new photovoltaic installations and a modest amount of new battery storage.

Through advanced controls and smart energy management, this new power system would help the township save on electricity costs during normal times and allow core facilities to remain operational during power outages. It would also allow the township to manage and maintain evacuation, rescue and supply routes to shore communities during a storm such as Hurricane Sandy.

Evans also directs NJIT's Center for Building Knowledge – a 30-year-old research, training and technical assistance institute affiliated with the university's College of Architecture and Design – which provides expertise on energy efficiency and resilience in the built environment.

The center's Clean Energy Learning Center, an online energy-efficiency training and resource platform funded by the U.S. Department of Energy (DOE) and developed in collaboration with TRC Solutions, will pilot-test energy-efficiency packages at colleges and universities in the state. Among other programs, the center also works with building owners to make quick, energy-saving upgrades in leased spaces and on a new certification program that uses a DOE tool to evaluate the energy efficiency of key physical assets within a facility – its building envelope, lighting and HVAC systems – and to tabulate a score.

The Future of Design Is Beyond Green

In January, DEANE EVANS was a juror for the "Beyond Green High-Performance Building and Community Awards," a showcase of edgy, socially conscious design held annually by the National Institute of Building Sciences. The "Innovation" category winner, a double-skin façade, is a shading device protected in a cavity that modulates solar heat gain. Assembled in a single factory with high-quality control, it requires no catwalk for maintenance access and is installed in one simple, cost-saving operation. Evans, who is a registered architect and fellow of the American Institute of Architects, reflects on the experience below.

Q: ***How does a design go "beyond green"?***
A: When we're judging a building's performance at this event, we're not paying lip service to 'green.' These buildings compete on eight different metrics, from sustainability, to security, to manufacturing and installation methods. It's hard to fire on that many cylinders at the same time.

Q: ***How does the contest reflect real trends in design?***
A: Increasingly, we're integrating higher and higher levels of performance in our buildings and other infrastructure. We now look, for example, at both sustainability – the impact buildings have on the environment – and resilience – how well they weather the environment's impact on them. It's a high standard. Those two goals cross over nicely, but they don't always. What enables a building to withstand a flood may not make it sustainable. Photovoltaic panels reduce power consumption, but aren't very sturdy in high winds.

Q: ***How can we make existing buildings greener and more resilient?***
A: We need to be very opportunistic about upgrades. We can insulate attics, repair roofs and seal leaky window frames, which helps on both fronts. We can install more efficient lighting and better performing HVAC systems. Landlords can do some of these things quickly when a tenant moves out. Building owners can assess the energy efficiency of their key physical assets and upgrade them. At the Center for Building Knowledge, we provide programs to do both.

Q: ***How can towns and cities achieve both goals?***
A: At the community level, microgrids are autonomous power networks designed to function when the grid goes down. Most of them incorporate a variety of local power sources – from combined heat-and-power turbines that produce electricity and steam, to stored power, to alternative energy – that are much greener than the typical load.

Developing Campus Entrepreneurs

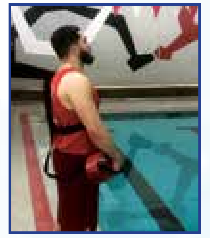
Fresh off Wall Street, **Michael Ehrlich** joined the management faculty at NJIT in 2007 determined to inject the energy and entrepreneurial creativity of the business world into applied research projects. His strategy was to start at the entry level – with students. That first year, Ehrlich co-founded the New Jersey Innovation Acceleration Center and launched the annual Newark Innovation Acceleration Challenge to spur students to think of their projects as startups with real-world implications. Capital One Bank agreed to sponsor it.

Each fall, budding entrepreneurs stand before a panel of judges, including local business people, to answer the following: why their product is needed; who is the target audience; how they propose to solve the problem they've identified; how their idea will make money; and how they best market rivals. Winners, including community participants in a separate cohort, secure $3,000 for a summer fellowship to develop their idea at Ehrlich's campus-based NJIT Lean Startup Accelerator. Other annual competitions and showcases for undergraduate research and invention – the TechQuest Challenge and Innovation Day, respectively – followed soon after.

"NJIT is naturally a hotbed of research and innovation and so we've focused on building the elements of an entrepreneurial ecosystem that will nurture and advance ideas originated here," he says. "These include a new innovation and entrepreneurship major and minor, clubs, funding programs and competitions to urge ideas forward."

With **Judith Sheft**, NJIT's associate vice president for technology development, Ehrlich went on to found a campus-based National Science Foundation I-Corps site in 2015 to fuel the development of marketable ideas from students and faculty. The first on a New Jersey college campus, it has funded more than 100 student-faculty teams so far. Of these, a dozen have gone on to secure $50,000 in venture funding from the national program.

Newark Innovation Acceleration Challenge



This year's winner: **Mark Quiles** '18, a finance and marketing major who created a company called League of Lifeguards that recruits lifeguards and matches them with jobs such as guarding at pools, parties and events like the Tough Mudder. Started last summer using social media, Quiles is developing the service into an app that will function like Uber or Airbnb.

National Science Foundation I-Corps Program

Chrystoff Camacho '18, an engineering technology major, and **Alec Ratyosyan** '18, a business student at Rutgers University, Newark, won both campus and national I-Corps grants to commercialize a data-driven management system to assist in reforestation. The system is designed to plant seeds using drones outfitted with customized hardware. Coupled to the device is a machine learning algorithm that provides data metrics on forest land holdings using remotely sensed images.

Makerspace at NJIT

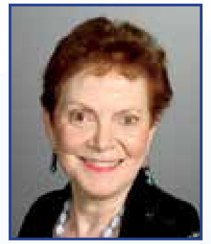
Early this year, the university opened Makerspace at NJIT, a 10,000-square-foot training-focused, rapid prototyping

facility, which provides equipment from small 3D printers to large industrial machines, such as precision measurement and laser-cutting machines. Plans to add electronic devices, a wood shop, a paint booth and soldering machines, among other equipment, and to double the space, are underway. "We'll be making suspension components, a custom gear box and gears – we'll probably use all of the machines in here," says **Christopher Eugenio** '19, captain of NJIT's Baja SAE team. "It's going to really help us in the troubleshooting phase when we can fix a part on the fly, by printing a new one in a couple of hours."

Undergraduate Research and Innovation Program

The Undergraduate Research and Innovation program provides space, funds for supplies and stipends year-round to students who are pursuing research or developing proof-of-concept prototypes. The Student Seed Grant Program awards $500 to students developing technology or products and $3,000 in a second phase for application-based research. Seventeen projects received funding for the fall semester. They include: an integrated power management system for solar cars; reactive nanobubble technology for sustainable environmental and agricultural applications; and 3D bioprinting of vascularized networks using hydrogels.

Partnering with Businesses



A century after Edison founded his first laboratory in Newark, the invention-rich industrial hub that produced patent leather, zinc electroplating, Celluloid plastic and Edison's stock ticker had lost its manufacturing edge. With an eye toward renewal, then NJIT President **Saul Fenster** created the Enterprise Development Center (EDC) in 1988 to nurture technology entrepreneurship. It now houses 85 companies.

"At that time, we were the only high-level, tech-focused game in town," notes **Judith Sheft**, associate vice president for technology development, who has led this charge for the university for the past 16 years. "Now the city is attracting big companies like Panasonic and Audible. Even more exciting, we have the intellectual capital and R&D infrastructure to ensure that tech startups can develop, grow and stay in Newark."

Sheft advances technology developed in NJIT's labs, provides market insights and connections for EDC companies, and puts on training and development workshops to help regional health care startups grow. With **Michael Ehrlich**, associate professor of finance, and the backing of JPMorgan Chase, she founded the Health IT Connections program to expand the region's health care cluster. She and Ehrlich also launched the annual TEDxNJIT conference to showcase future-focused ideas and innovations from the campus and community.

Critically, Sheft links students with the region's expanding research and innovation infrastructure, encouraging them to participate in off-campus technology conferences and competitions, while also connecting them with local tech startup companies. In a typical year, EDC companies employ scores of NJIT students. "These opportunities are launching our graduates into entrepreneurial careers of their own," says Sheft.

Enterprise Development Center

4.0 Analytics embodies the community-engaged and supported business model typical of the development center's tenants. The company developed a wireless emissions compliance and reporting technology for cars and trucks that alerts automobile owners in real time – on their own smartphone devices or computers – to engine and emission-system malfunctions that can lead to excessive tailpipe releases and poor performance. "It's almost impossible to manage something if you can't measure it," explains **Mark Scotland**, the company's CEO. "Bringing transparency to the heart of the vehicle – its engine and emissions system – is the key to preserving the life of a very expensive asset." The device has been greeted enthusiastically by NJIT, Rutgers University-Newark and others, who have tested it in their fleets. Two NJIT graduate students, **Sandeep Raveeshbabu** and **Krutarth Patel**, helped develop it.

New Jersey Innovation Institute

New Jersey Innovation Institute
An NJIT Corporation

New Jersey Innovation Institute (NJII) is an NJIT corporation focused on helping private enterprises meet the challenges shared across an entire sector, while helping individual companies develop new products and market opportunities, as well as strategic business partnerships that embrace emerging technology. NJII has strategically organized Innovation Labs (iLabs) focused on health care delivery systems; biotechnology and pharmaceutical innovations; civil infrastructure policy and planning and smart cities; defense and homeland security; and financial services. Backed by about $8 million from the U.S. Department of Defense, NJII works, for example, with aerospace and defense contractors in the state to develop new products for existing markets and new customers for the products they already manufacture.

JPMorgan Chase & Co. Small Business Forward℠

New Jersey Innovation Institute (NJII) was one of the inaugural grant recipients in the JPMorgan Chase & Co. Small Business Forward℠ initiative, a five-year, $30 million program designed to boost small business support networks that help growing enterprises in specific industries. The program connects entrepreneurs with resources to help their businesses grow, create jobs and strengthen communities. NJII launched the Health IT Connections program to help growth-stage health IT entrepreneurs who have achieved initial market traction of $250,000 in revenue and need support to accelerate their commercialization pathway. Through group classes and networking events, the objective is to help them achieve 20 percent or more annual revenue growth.

Eliminating Medical Error Through Bioinformatics

Graduate students Vipina Kuttichi Keloth (left) and Hao Liu (right) discuss medical terminologies with James Geller, co-director of NJIT's Structural Analysis of Biomedical Ontologies Center.

In an age of increasing reliance on computers, digitizing patient medical records has emerged as the driving force behind the health care industry's expanding, interconnected information networks.

Thanks to the rapidly growing field of medical informatics – an amalgam of computer science, information science and information technology – health care providers are no longer obligated to rely on antiquated paper-based systems. Nowadays, with just a few mouse clicks, physicians can tap into a robust network of electronic health records (EHRs) for quick retrieval of a patient's comprehensive health information.

The systemized acquisition, retrieval, storage and sharing of data – on everything from medications, allergies and immunization dates to vital signs, radiology images, and lab and test results – have produced improved patient outcomes and care coordination. Through enhanced aggregation, analysis and communication, there's also been a reduction in preventable mishaps, such as adverse drug reactions, which, according to data from the Centers for Disease Control and Prevention, harm anywhere from 1.9 to 5 million inpatients per year.

"Medical informatics saves lives," says **James Geller**, a professor of computer science, who, along with Professor **Yehoshua Perl**, co-directs NJIT's Structural Analysis of Biomedical Ontologies Center (SABOC), where a team of research scientists develop software to streamline medical terminologies that support the integration of data into EHRs.

"Not every doctor can remember every such interaction for every medicine prescribed by different doctors," Geller explains.

For example, if a patient has a pre-existing kidney condition, "a good EHR would uncover all the potentially dangerous prescription interactions and alert the doctor," he adds.

Despite the clear advantages to utilizing an all-inclusive system to convert health care data into actionable intelligence, there are still "some doctors who are reluctant to accept the blessings of modern computing technology," notes Geller.

To incentivize old-school clinicians to go digital, in 2009 the American Recovery and Reinvestment Act authorized payments to eligible hospitals and health care providers who recorded patient information as structured data. The recent uptake in EHR usage has positioned SABOC, which is backed by a three-year, $1.75 million grant from the National Institutes of Health, as a resource for informaticians and curators eager to grow repositories of error-free biomedical information.

"We develop methodologies and quality assurance practices to simplify and detect inaccuracies in complex medical ontologies," says Geller.

The terminologies include drugs and diseases, diagnoses, medical procedures and devices, chemicals in drugs, body parts, microorganisms, genes, infectious agents and accidents, among others.

His team has joined forces with Mayo Clinic and other scholars, such as Stanford University's **Mark Musen**, a professor of bioinformatics who developed Protégé, the world's most widely used technology for building and managing terminologies and ontologies.

"We have been able to create a plugin for Protégé that is now available on Stanford's website, and visible to all Protégé users," says Geller. "The eventual goal of medical informatics is to have all of a patient's health care data collected in one single EHR. That would open the door for computers to notice drug-drug interactions and adverse drug reactions – and save more lives."

Transforming Clinical Practice at the System Level

Backed by a nearly $50 million grant from the Centers for Medicare & Medicaid Services (CMS), NJIT's NEW JERSEY INNOVATION INSTITUTE (NJII) has established the Garden Practice Transformation Network (PTN) to work with CMS as part of the organization's Transforming Clinical Practices Initiative, which aims to save more than $1 billion in health care costs by the end of 2019.

The CMS program is designed to move practices from a fee-for-service payment model that reimburses caregivers for dispensing treatment at episodic visits to what is known as a "value-based" care system that compensates them for keeping their patients well by adhering to ongoing, evidence-based disease management. The program is aimed in particular at the sickest patients with complex conditions such as diabetes and cardiovascular disease who often cycle in and out of emergency rooms, as well as have longer hospital stays.

The NJIT group is currently working with nearly 10,000 providers from New Jersey, Maryland and Puerto Rico, who are responsible for more than 500,000 patients.

"Garden PTN is demonstrating that collaboration between providers, the federal government and technology can indeed achieve the health care triple aim of lowering costs, improving care and enhancing the patient experience," says VAN LY, senior director of Garden PTN, adding, "The network is on pace to save well over its original goal of $155 million."

NJII's practice transformation program builds on the success of an NJIT-led health IT startup, NJ-HITEC, formed in 2010 to train 5,000 primary care providers in the state to adopt electronic health record (EHR) systems in order to keep better track of their patients and improve care. Participating practices were required to demonstrate that they collected, stored and acted on key data such as medications, allergy lists, diagnoses, vital signs and clinical quality measures, among other health metrics. Under the new program, NJII will revisit these practices to analyze the quality data that they have been collecting and educate providers on best treatment practices nationally to further improve health outcomes.

A Scientist Mulls the Question: If Lectures Can Be Viewed Online, Why Come to Campus?

Eric Fortune
Associate Professor, Biological Sciences

"By working shoulder-to-shoulder with mentors in the lab, conducting experiments that reveal the unknown structure and organization of our world, students not only learn new concepts and facts, but also begin to understand how they are established in the first place," reflects neuroscientist Eric Fortune (right) with a student in his Laboratory for Neurobiology and Behavior.

It's true that anyone can read the books we review in class, watch lectures covering any and every topic for free online and share ideas with peers on social media. So if books and lectures are not what make a university education valuable, what does? I would say that the most profound educational experience universities have to offer students is the opportunity to participate firsthand in the generation of new knowledge.

By working shoulder-to-shoulder with mentors in the lab, conducting experiments that reveal the unknown structure and organization of our world, students not only learn new concepts and facts, but also begin to understand how they are established in the first place.

In my laboratory, we focus on how the brain interprets the sensory world we live in and how brain circuits control behavior. We identify and measure these links through neurophysiological experiments. To do this, we place wires that are finer than the width of a human hair in the brain to record the electrical activity of neurons.

For students, lab work is like a truly active, specialized course with a class size of one, and their understanding deepens accordingly. When students start off in the lab with only a cursory idea of what we do, their level of misunderstanding can be quite profound. They don't yet understand the bridge between the ideas they read about in books and the methods we use to evaluate and even reject these ideas. They don't yet appreciate the linkage between data and insight.

They are often simultaneously awestruck and overwhelmed when they hear the characteristic popping sound of electrical brain activity for the first time. But over time, they grapple with the complex data-crunching that convert those raw data into statistically testable analyses of brain organization. And within months, some students can master the tools, techniques and skills necessary to conduct these challenging experiments on their own.

It is also true that these neophyte researchers play a critical role in the intellectual progress of their mentors. Interactions with gifted students can challenge and even overturn deeply held intuitions. More generally, their understanding of the world, so often quite different from mine, can lead to new perspectives on our research. On one hand, they have recently taken courses that I took 20 years ago, and those disciplines use new tools and techniques, including advanced statistical methods and new technologies. On the other hand, their views and instincts about the natural world have been shaped by vast differences in our cultural understanding of humans' place in the world and their own experiences in nature.

Indeed, I've found these exchanges can provide the secret sauce that inspires deep academic insights. Simple questions can lead to discussions that take us into unexpected gaps in our knowledge and understanding. A biomedical engineering student's question about a concept taught in every first-year neuroscience course, the 'receptive field' - features for which a sensory neuron is activated – led to an hours-long discussion which resulted in a complete reorganization of the experiment we were conducting together. I personally was shocked that I had overlooked such a glaring and, in retrospect, obvious insight. The feeling was similar to finally solving a dogged crossword clue, but on a much bigger scale!

Like solving a puzzle, however, sometimes our hard-fought insights, although personally satisfying, can seem as though they are little more than scientific trivia. In the lab, we're often focused laser-like on a tiny facet of our world, spending hours of work and frustration to try to understand some feature that most people don't even know exists. Alas, we know from many Nobel prizes that world-changing insights have come from seemingly esoteric studies of fruit flies, microscopic worms and sea slugs.

And yet, is this laborious acquisition of knowledge, obtained through tiny steps in the lab, valuable in and of itself? Is participating in research the most profound educational experience at a university? Certainly some of my students will go on to become doctors who treat patients, and they need to know how the science that leads to new therapies is conducted. But there is something larger at stake, which is the nature of truth.

Fundamentally, research is about discovering the true nature of our world. I think it's critical for students to experience the challenge of discovery – of revealing hidden truths about the world. The importance of pursuing the truth – and the ability to assemble the evidence that is required to elucidate truth – is a principle that will serve them well in every aspect of their lives.

ERIC FORTUNE is the director of NJIT's Laboratory for Neurobiology and Behavior, which examines the interactions between sensory and motor systems that are used to generate and control animal behavior. In the lab, he focuses on two questions primarily: how sensory representations of movement are encoded by sensory systems and translated into motor commands, and how pairs of animals integrate social cues in the control of cooperative behaviors. His research methods include highly controlled behavioral studies in the laboratory, and a variety of neurophysiological approaches to central nervous system neurons in animals, pharmacological studies and mathematical modeling. He regularly takes students on field studies of natural behavior in Amazon basin habitats and in the Galapagos Islands.

A Glimpse Into Three Campus Research Labs Reveals: Humanized Technology, 3D-Printed Biomaterials and Blind Fish

For NJIT students, the ideas that spark research projects are as diverse as they are.

What they share is the determination to find laboratories, mentors and funding, and the imagination and skill to apply technology to daily problems, using the resources around them. At the start of each semester, Atam Dhawan, senior vice provost for research, solicits proposals for Undergraduate Research and Innovation (URI) grants to get the ball rolling.

"Whether it's an app you're designing, a device you're inventing or fundamental scientific research you're helping to rethink, start the process by sending us your ideas," Dhawan urges. In response, he receives proposals for high-tech approaches toward disease treatment, with nanotechnology-controlled medications and through tissue engineering; experiments connecting data-collecting ham radio operators with space scientists; and virtual games used in neurorehabilitation, among others.

But research lives on after the school year ends. Each summer, more than 125 students win funding to return to campus to dig deeper into projects. As part of the university's URI summer session, they are backed by a range of sponsors – the URI program, NASA, the National Science Foundation, the Hearst Foundation, Capital One Bank, PSEG and the James Stevenson and Family Foundation, to name a few – and work with more than 70 NJIT faculty and research staff members.

Increasingly, undergraduates are taking their innovations on the road: to technology conferences, along commercialization pathways such as the National Science Foundation's I-Corps program and before local venture investors. As John Vito d'Antonio-Bertagnolli, a former biomedical engineering student, said of that first major funding pitch, "This was an entirely different experience convincing strangers to back us on something we hadn't done yet." Two years later, he's founded a technology company.

Social Interaction Laboratory
Donghee Yvette Wohn, Director

The Social Interaction Lab is an interdisciplinary research hub that combines psychology, communication, computing and design to understand how people interact with technology. The lab focuses in particular on studying technologies that are social, such as mobile-health apps, multiplayer games and social media. Many of the recent projects revolve around technology and mental health, including the development of a mobile app to support women in STEM, the use of bots to provide social support in virtual environments, and an examination of how algorithms and human moderation practices help combat online harassment.

"The primary question my students and I explore is how technology facilitates positive or negative interactions between people and society. One of the goals of our research is to see if we can replicate and provide human warmth and a sense of personal connection through the devices and programs we create or adapt. We look for ways to make computer programs and apps more personable, including adding physical stimuli and incorporating social bots."

CHATBOT JUAN RIOS '18 and VICTOR CHUE '18 were curious about the effect of temperature on interactions with conversational agents, or chatbots, similar to Siri or Google Assistant. "If you were warmer, would you feel more open toward it?" Rios explains. Participants held human-like conversations with a chatbot, first with no stimulus and then while gripping either a cold or hot object. They compared feelings of closeness. "Some people were weirded out. Others noticed no difference," notes Chue. Fellow researchers were intrigued, however. The pair was invited to present their published work at GROUP, the Association for Computing Machinery conference.

Virtual Sisters

VIRTUAL SISTERS A team of eight students from five disciplines joined forces to develop a mobile application called "Virtual Sisters" to provide a virtual community for women in STEM majors. "Women are still underrepresented in STEM, and, for that reason, can have difficulty identifying mentors and peers," posited INDRANEEL KULKARNI M.S.'17, the team's Android developer. The app gave students a private space to discuss their experiences, ask questions and form connections with people across departments they may never have met in class. Women said replacing the "like" button with "hug" amplified feelings of connection and support.

TALKING HEALTH CARE ON THE STREETS OF NEWARK Biology student BASMA ABUKWAIK '17 wanted to know whether women in Newark would be willing to use telehealth applications, specifically video-conferencing on their smartphones, to connect with providers such as doctors, nutritionists and life coaches. Binder in hand, she hit the streets to ask city women 10 questions – and got some surprising answers. "The bigger question is how technology can fill health care gaps for people who lack access," she recounts. "A nursing student I interviewed on the street said it might be better to improve transit systems so people could get to their doctors."

Instructive Biomaterials and Additive Manufacturing Laboratory

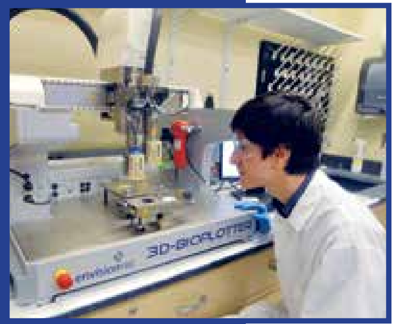
Murat Guvendiren, Director

Despite significant efforts, the lack of organs and tissues for transplantation poses a major hurdle in medicine. The Instructive Biomaterials and Additive Manufacturing Laboratory (IBAM-Lab) develops novel approaches to address this gap. The lab designs biodegradable polymers and hydrogels with user-defined and tunable properties; engineers medical devices, tissues and organs using 3D-bioprinting; develops material-based technologies to control stem cell differentiation; and fabricates patient-specific in vitro disease models for fundamental studies and drug screening. Additionally, IBAM-Lab devises novel strategies for biomimetic material design, stimuli-responsive materials, surface patterning and photopolymerization. The facility includes a wet lab designed for polymer discovery, synthesis and processing, and a biolab for elucidating cell-material interactions in vitro.

"My students and I take a multidisciplinary approach toward developing innovative treatment alternatives using novel biomaterials with 3D-bioprinting, including the biofabrication of tissues and the development of tissue-engineered scaffolds and medical devices. I am particularly motivated to develop mini projects designed for undergraduate students, which are parts of much larger projects. I also encourage them to do fun stuff such as printing chocolate."

BRIDGING THE INTERFACE BETWEEN CARTILAGE AND BONE

Using computer-aided design and a 3D printer, HAZAL YALCIN '18 is designing a gradient scaffold to help knit together damaged bone and cartilage at the interface where the two tissues rub against each other and wear each other down. "Bone and cartilage are two different tissues with different properties, so in order for them to heal at the same time, I'm creating two scaffolds and combining them. I then test them under mechanical forces to see what sort of scaffold patterns bear the load best," she says, adding, "It's really useful – and interesting – to see how tissue regenerates."



FORMING WRINKLES ON 3D-PRINTED HYDROGELS

Using a 3D bioplotter, JORGE PEREYRA '18 is creating wrinkle patterns on hydrogels – some wavy and random and some highly ordered hexagonals – which he then layers into a three-dimensional matrix to support cell growth. "We'll study the behavior of cells in these different patterns," he says, "and try to determine where they grow best." But there are many other potential applications for printed hydrogels, he adds, including adhesives, microdevices and sensors. For insurance purposes, for example, a company could coat a cellphone with material that "wrinkled when it came in contact with water."

BIOPRINTING BLOOD VESSEL NETWORKS

EMILY ALMEIDA '18 is 3D bioprinting vascular networks using hydrogels. Within the context of tissue engineering, networks of blood vessels will be "essential to allow nutrient transportation and waste removal in cells," she says. Prior to printing, she tested several parameters to achieve the desired mechanical properties and dimensions. Once the final scaffold was printed, she incorporated cells and growth factors into the matrix. Of the lab, she notes, "We're all working on different aspects that will at some point come together in a human mimetic prototype."

Neuroecology of Unusual Animals Laboratory

Daphne Soares, Director

How do nervous systems evolve and adapt to extreme environments? The Soares lab uses neuroethological and ecological methods to understand the evolution of neural adaptation, examining the evolution of circuitries, behavioral adaptation and sensory novelty. This integrative approach links a detailed characterization of the environment with the anatomy and function of neural systems within a phylogenetic context. Soares and her students study the blind cavefish Astyanax mexicanus, found in central Mexico, which is born with eyes and lenses that disintegrate in early development. They compare these fish to their closet living ancestors, Astyanax that live on the surface. The two fish can still interbreed.

"In my lab, students look at development from a number of perspectives, from morphology, to physiology, to behavior. We explore small developmental changes to understand the big picture of evolution. We can study, for example, various aspects of how neural circuits have evolved from the ancestral surface form to a derived cave form."

CAN BLIND SPECIES COMPREHEND SIGHT?

Soares expects that cave and surface fish have the same neural coding for vision as larvae; the lab is investigating how it changes as fish become blind, raising a question: If scientists could reverse the process, would an animal destined to be blind be able to comprehend sight? "I'm looking at the brain function that interprets sight, measuring calcium levels in the cells that might permit vision to assess their activity," says SHAIZA ALI '18. So far, it appears that surface fish begin to modulate visual stimuli, neurons firing with a coherent code, while cavefish continue to exhibit a lot of spontaneous activity.

HOW CAVEFISH TRADE EYESIGHT FOR SURVIVAL

Detecting water flows is advantageous to a blind fish, because the environment, prey and mates create disturbances the cavefish can interpret. SAM KOLAWOLE '18 looks at the development of the sensory cells called neuromasts in both forms of the fish. These cells, located on the surface of both young fish and adult cavefish, are more concentrated in the cavefish, giving it a high level of water flow processing capability. He's trying to understand at what point this difference appears in development. "I map each neuromast using a fluorescence microscope to create a map that changes with age."

DEPICTING THE EVOLUTION OF SIGHTLESS FISHES

ALEX BRADBURY-WALLAD '16, a digital design major with a passion for science, received an offer he couldn't refuse: the chance to collaborate on media projects with Soares, a scientist intrigued in turn by the communicative power of art and design. He noted, "I still love biology, and I'm especially interested in extremophile species." Based on CT scans, he constructed animated sketches of cavefish brains and a series of 3D models illustrating the evolution of sightless fishes in dark caves. The pair followed up with an educational video showing how cavefishes adapted to their extreme environments by losing their eyes and pigmentation.

Driving Innovations in Orthopedic Implants

Robert Cohen, a biomedical engineer and entrepreneur who specializes in orthopedic joint replacement implants, years ago envisioned the convergence of advanced materials, new fabrication methods and robotic-assisted surgery to maximize motion restoration. In 2010, his New Jersey company, Pipeline Orthopedics, the developer of implants with porous metals designed to improve the fixation of device and bone, entered a strategic alliance with Mako Surgical Corp. in order to use Mako's robotic systems in the operating room to help place its implants more precisely. During that same era, Pipeline 3D metal-printed one of the first orthopedic devices approved by the U.S. Food and Drug Administration for human orthopedic implantation. Cohen now heads the 600-person research and development team for the joint replacement division of Stryker, the medical technology giant. Last year alone, 42,000 people underwent robotic-assisted surgeries to implant the company's knee and hip devices. Below, Cohen discusses the recent burst of innovation in the implant sector, propelled on many fronts by advances in engineering.

Q: WHAT IS DRIVING INNOVATION IN THE JOINT REPLACEMENT SECTOR?

A: Expectations are changing. People are living longer, employed longer and physically active longer. In the 1980s – the early days of implant technology – the idea was to permit basic functioning, such as getting out of bed or into a car. Today, people are returning not only to work in many cases, but to tennis and golf. With the relief of joint pain, they want back everything they had in life. Increasingly, they are considering interventions earlier in life, so they don't have larger problems later.

Q: WHAT ARE THE ENGINEERING CHALLENGES?

A: People seeking implants want more durable clinical results and a high level of satisfaction in the near- and long-term. For engineers, the challenge is complex. We need to design implants that last a long time, while also striving to give people back the same range of motion they once had. And patients want to feel better as soon as reasonably possible. This means both the implant design and the surgical technique needed to evolve in order to shorten hospital stays and potentially quicken recoveries. As engineers, we will meet these rising expectations with innovations in biomaterials that interact more physiologically in the joint *and* implant designs that are placed on the bone more precisely to meet individual patients' needs and function.

Q: WHAT ARE THE KEY TECHNOLOGICAL ADVANCES IN BIOMATERIALS AND DEVICE DESIGN?

A: We have developed an implant with a porous metal exterior surface made by additive manufacturing. It is produced with a specific 3D printing process known as "direct metal laser sintering" in which a laser is programmed to consolidate titanium alloy powder in a configuration that engineers create with a computer model. The resulting structure is fully solid internally with an external surface porous matrix for new bone to grow into.

There are two other important technology advances. We have a growing database of 3D computer models of joint bone images, and, based on this, we can design implants with more information than ever before. These images also guide us in determining where an implant can better fit a person's anatomy, while restoring that joint's motion. The 3D metal printing process is such a departure from metal machining methods of the past, that it is allowing us to think differently. We can now shape metal in a way conventional manufacturing never could. We no longer have to think of an implant configuration that only a lathe, a mill or a casting can make. Patients are benefiting from these new 3D-printed implant geometries.

Q: WILL YOU DESCRIBE A SURGERY?

A: Before we begin surgery, we now have a very specific idea of exactly where the implant will go in each patient. CT scans of the patient's bones are converted to a three dimensional computer model. Pre-operatively, the implant models are superimposed over the bone models where the surgeon deems best. That combination implant-bone model is now the preliminary plan and it's transferred the day of surgery to the Mako system in the operating room. Mako is comprised of a computer and a robotic arm. The cutting instrument that prepares the bone to accept the implant is attached to the end of the arm. The surgeon moves the instrument with the robotic arm, defining the limits of the bone cut surfaces, essentially creating 'virtual boundaries' determined by the patient's hip or knee CT scan and the surgeon's assessment of the patient intraoperatively. Robotic-assisted surgery provides for implant placement precision and accuracy we have never seen before with other surgical procedure technologies.

NJIT alumnus Robert Cohen, a biomedical engineer and entrepreneur, specializes in orthopedic joint replacement implants that exploit the convergence of advanced materials, new fabrication methods and robotic-assisted surgery to maximize motion restoration.

Q: WHAT'S ON THE HORIZON FOR IMPLANT SURGERY?

A: We are making advances on several other fronts, including an effort to make incisions and devices smaller as we design and place implants on individuals' bones less invasively. The goal is to disrupt less soft tissue and remove less bone. These improvements come at the nexus of evolving robotics, smarter engineering and more sophisticated 3D printing. Looking at the implant sector from the perspective of both an engineer and an R&D executive in a medical device company, we are able to design better implants in unique shapes in conjunction with precise bone preparation that is robotically enabled.

NJIT ALUMNI AT STRYKER

PETE ABITANTE	SHAWN KROLL	EMILIO SANCHEZ
Vice President of Reconstructive Implant Product Development	Vice President for Robotics Development	Senior Business Development Director

Q: HOW IS THE INDUSTRY-ACADEMIA NEXUS IN THIS SECTOR EVOLVING?

A: The partnership between academia and industry has such potential, but progress here is slow. Taking the initiative, we've started canvassing universities looking for areas of expertise that can accelerate our development cycle and bring novel medical devices to the market. I think these relationships will prove very useful. Professors are very good at specialization, while the type of labs they run are too speculative and often too expensive for private industry to consider at that early a stage. We are starting to form partnerships with academic labs to work on everything from cell biology, to radiographic image modeling, to new biomaterials, to 3D printing, to end effectors on robots. Indeed, some of the students we've gotten to know at my alma mater through industry-mentored capstone projects or internships are now working at Stryker. It's an interesting time in orthopedic joint replacement with new technologies allowing engineers to take a fresh look at everything we do and how we design. Innovation is thriving.

New Faculty

In its mission to translate scientific discovery into beneficial applications and devices to meet pressing needs, NJIT focuses on four areas of multidisciplinary research that represent the university's core strengths: data science and information technology, the nexus of life sciences and engineering, sustainable systems, and a transdisciplinary category that addresses the large systemwide challenges of "smart cities" and other complex organizations. To make good on this promise, the university's strategic plan, *2020 Vision*, calls for a multiyear hiring effort that will expand the faculty from 280 in 2014 to 345 by 2020. Here are the most recent additions:

COLLEGE OF SCIENCE AND LIBERAL ARTS

PHILLIP BARDEN, assistant professor of biology, combines paleontology, bioinformatics and X-ray imaging to interpret the earliest known fossil evidence for social behavior in ants and termites. He uses genetic data to identify convergent trends, as well as the genomic foundations and consequences of highly social behavior.

ROSANNA DENT, assistant professor of history, studies the social and political roles of science in Latin America. In a recent book, she examines interactions between scholars and Xavante villagers in Central Brazil, showing how indigenous subjects have shaped and used research for their own goals.

CHRISTINA FREDERICK, assistant professor of mathematical sciences, focuses on multiscale methods, a branch of computational and applied mathematics advanced by developments in computing technology and information science, which enables the examination of a problem from several different scales and levels of detail simultaneously.

ELIZABETH NOWADNICK, assistant professor of physics, combines quantum mechanical simulations, structural chemistry and theoretical models to explore the properties and functionality of complex oxides and other complex materials. They include a new class of ferroelectric materials, which exhibit an electrical polarization reversible with an electric field.

ANAND OZA, assistant professor of mathematical sciences, is a theorist interested in fluid mechanics and nonlinear dynamics. Applications include the physics of soft-matter – deformable materials such as liquids and polymers – and biology, as in the collective behavior of fish schools as mediated by fluid mechanics.

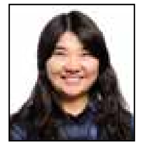
REBEKAH RUTKOFF, assistant professor of humanities, writes both creative and non-fiction works on topics ranging from ancient medicine and avant-garde film and art, including the pioneering computer artist Lillian Schwartz, who created multiplatform works at Bell Labs in the 1970s.

KRISTEN E. SEVERI, assistant professor of biological sciences, studies the neural circuits in zebrafish that initiate and modulate swimming behavior, using kinematics, calcium imaging, electrophysiology and a tool she co-developed to study living fish that uses a genetically controlled form of Botulinum toxin to silence neurons.

NEWARK COLLEGE OF ENGINEERING

PRAMOD ABICHANDANI, assistant professor of engineering technology, researches multidimensional, data-driven decision-making using mathematical programming, linear and nonlinear systems theory, statistics and machine learning. Applications range from the control of robotics systems, to data-driven decision-making using probability models, to online engineering education.

İ. ESRA BÜYÜKTAHTAKIN, associate professor of mechanical and industrial engineering, develops mathematical models and algorithms to help policymakers tackle sustainability and health care problems, including the management of pests that wreak havoc on forests and the optimization of chemotherapy strategies for patients with breast cancer.



HUIRAN JIN, assistant professor of engineering technology, develops geospatial analysis and modeling applications to improve remote sensing applications, such as land-cover and land-use mapping, wetland-inundation monitoring, urban-growth detection, and crop-growth modeling and yield estimations. Her models reveal the wetland hydrology and ecosystem function of local landscapes.

SIMONE MARRAS, assistant professor of mechanical and industrial engineering, explores problems in computational fluid mechanics. His interests range from the numerical study of turbulence in free surface flows, to the aeroacoustics of wind turbines and large wind farms in the atmospheric boundary layer, to numerical modeling of tsunami-triggered flooding.

KATHLEEN McENNIS, assistant professor of chemical and materials engineering, concentrates on developing multicompartmental nanoparticles for drug-delivery applications. She uses physical chemistry characterization techniques in novel ways, including the use of light scattering and calorimetry, to investigate drug-delivery vehicles in biological environments.

LUCIA RODRIGUEZ-FREIRE, assistant professor of civil and environmental engineering, harnesses the interaction between biological and inorganic systems, such as microorganisms and metals, to investigate the effect of contaminants on natural biogeochemical cycles, to remediate polluted sites and to predict and avoid future environmental damage.

YING WU COLLEGE OF COMPUTING

AMY K. HOOVER, assistant professor of informatics, who researches AI-based human-computer collaboration, focuses on creative computing with applications in games, artificial intelligence, and music and sound. She developed a functional representation of music based on patterns of pitches and durations used in software to help amateurs compose.

IOANNIS KOUTIS, associate professor of computer science, designs tools capable of probing large networks based on fast linear system solvers and other numerical algorithms. Additionally, his 'algebraic fingerprints' method enables the design of faster, exact and parameterized algorithms for a multitude of challenging computational problems.

JING LI, assistant professor of computer science, researches real-time systems, parallel computing and cyber-physical systems. In exploiting untapped efficiencies in multicore computing, she improves the scalability and quality of service in cyber-physical systems and interactive online cloud services, with applications in robotics, web searches and online gaming.

DAVID SHAOHUA WANG, assistant professor of informatics, concentrates on the intersection of software engineering and machine learning, with applications in smart and secure software systems that optimize users' interactions with software. His system for analyzing big user data automatically assists people in filling out web-based services, eliminating repetitive typing.

MARTIN TUCHMAN SCHOOL OF MANAGEMENT

JORGE FRESNEDA, assistant professor of digital marketing and marketing analytics, explores the role of information in online consumer reviews, with a particular focus on review helpfulness. His research focuses on applications of artificial intelligence, text mining and big data analytics tools to solve problems in the field of digital marketing.

RAJA ROY, assistant professor of innovation and entrepreneurship, studies firm-level capabilities, such as access to complementary technologies and in-house users, during technological disruptions of machine tools, industrial robotics and image sensors at high-tech companies. His databases include, for example, detailed information for nearly all products manufactured across an industry.

STEPHEN TAYLOR, assistant professor of finance, is interested in the application of mathematics, statistics and optimization methods to practical data analysis problems in the social sciences. He has previously worked in industry at several investment banks and hedge funds implementing risk and performance metric monitoring software.

NATIONAL SCIENCE FOUNDATION CAREER GRANT RECIPIENTS

ALICE LEE, associate professor of biomedical engineering, develops in vitro tissue models and novel bioreactors, focusing recently on cardiovascular tissue engineering. She has developed spontaneously beating heart chambers exhibiting key characteristics of the native heart for the first time. Her grant – to reveal the underlying mechanisms of heart tissue repair with cell-based therapy following infarction – will address a gap in understanding: limited knowledge of the biological mechanisms of those transplanted stem cells, which has hindered efforts to restore tissue damaged by a heart attack.

SIVA NADIMPALLI, assistant professor of mechanical and industrial engineering, specializes in fracture mechanics. He develops new methods for examining the breakdown of the materials and interfaces in batteries that connect the active particles responsible for energy storage. Their durability is critical for sustaining electrochemical reactions. His award targets a roadblock in the development of high-capacity, affordable and long-lived batteries that could power commercially viable machines such as electric cars, and lead to improvements in applications in the aerospace and biomedical device sectors that require powerful, lightweight batteries.

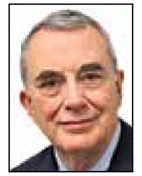
BIN CHEN, assistant professor of physics, investigates solar flares and coronal mass ejections, the largest explosions in the solar system that are responsible for the powerful atmospheric disturbances known as space weather. Using a new generation of radio telescopes, including NJIT's Expanded Owens Valley Solar Array and the Jansky Very Large Array, the award will allow him to advance understanding of the Sun's physical mechanisms responsible for releasing large amounts of energy catastrophically and accelerating charged particles to high energies in a short timescale.

SAGNIK BASURAY, assistant professor of chemical and materials engineering, identifies synergies among novel nanostructures, optics, biology and electrokinetics in order to develop new technologies in sensors, diagnostics, drug-delivery mechanisms and biofilms. His grant will advance the development of a novel electrochemical sensing method to be used in biosensors for early-stage diagnosis of infectious diseases and cancers. Current detection methods often fail at low concentrations as they are not sufficiently sensitive to prevent false-negative diagnoses, nor selective enough to prevent false-positives.

DEFENSE ADVANCED RESEARCH PROJECTS AGENCY (DARPA): YOUNG FACULTY AWARD

KURT ROHLOFF, associate professor of computer science and director of NJIT's Cybersecurity Research Center, develops open-source hardware, such as graphics software and wireless communication software, which is written and optimized for off-the-shelf hardware. It is often prohibitively expensive to use open-source software on many projects, thus impacting the effectiveness and security of resulting solutions that need to be built from scratch at low cost. The grant will support research to improve the utilization of open-source software, with specific applications for cryptography and cybersecurity.

NATIONAL ACADEMY OF ENGINEERING: ARTHUR M. BUECHE AWARD

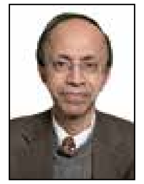


LOUIS LANZEROTTI, distinguished research professor of physics, is best known for shedding light on Earth's near-space environment and its impact on hardware in space and critical infrastructure on the ground. He played a central role in preparing the first satellites for travel in what was then a little-known realm subject to powerful geomagnetic fields and radiation, while also designing research instruments for NASA space missions. The academy credits him with advancing the public's understanding "of these invisible but potent forces" through a variety of influential media.

AMERICAN MICROCHEMICAL SOCIETY: BENEDETTI-PICHLER AWARD

SOMENATH MITRA, distinguished professor of chemistry and environmental science, has won global prominence for his work in several areas, including trace measurements in waste streams and diverse nanotechnology applications ranging from gas chromatography columns, to flexible batteries, to sea water desalination. His work in real-time trace measurement plays a central role in environmental monitoring, including techniques for parts-per-billion-level measurements in ambient air and industrial stacks. By immobilizing carbon nanotubes in membrane pores, Mitra has created novel architectures for the membrane distillation process.

ALAN S. MICHAELS AWARD FOR INNOVATION IN MEMBRANE SCIENCE AND TECHNOLOGY



KAMALESH SIRKAR, distinguished professor of chemical engineering, is a noted developer of industrial membrane technology used to separate and purify air, water and waste streams and to improve the quality of manufactured products such as pharmaceuticals, solvents and nanoparticles. The recipient of 30 patents, he is best known for developing the concept of membrane contactors. This filtration process permits two phases, such as a liquid and a gas, to meet at the pores of a membrane – without dispersing into each other – to introduce or extract specific compounds across it.

NATIONAL ACADEMY OF INVENTORS

YUN-QING SHI, professor of computer engineering, devises methods to hide and retrieve data embedded in digitized images and speech. Data-hiding techniques are used to protect and verify intellectual property such as photos that have been digitally "watermarked" and can be accessed only by unlocking the encrypted information within the image. More recently, Shi has developed methods for returning these images to their untampered form after the embedded data have been removed. He is also an expert at determining whether digital information, including speech, has been altered.

NJIT's Research and Innovation Index

77%
Increase in external research funding since 2014

85
Life science and technology companies in NJIT's Enterprise Development Center in 2017

$2.3 MILLION
Amount spent on undergraduate student research stipends and grants since 2015

71
Number of research laboratories and centers on campus

2
Number of spacecraft containing NJIT research instruments

2017 WINNER
Undergraduate TechQuest Challenge: a hydrogel-based therapy to treat diabetic retinopathy, the leading cause of blindness worldwide

108
Number of new faculty hired since 2013

20+
Number of NJIT instruments in Antarctica

330
Number of patents and intellectual property assets held by NJIT faculty

9
Winners of National Science Foundation CAREER Awards since 2016

130
Number of undergraduates who spent the summer of 2017 on campus working on funded research projects

$49 MILLION
NJIT's largest research and development grant

NJIT
New Jersey Institute of Technology

njit.edu/research

University Heights
Newark, NJ 07102

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