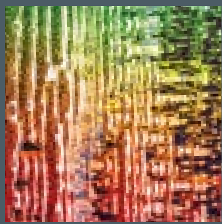

SERENDIPITOUS SELF-ASSEMBLY

In suspension, particles reveal a synchronized choreography.

See page 16

A MOST USEFUL NEW ALLIANCE

A summer camp yields benefits for biologists and engineers.

See page 22

resolve

A FOCUS ON LEHIGH ENGINEERING • VOLUME 1, 2014

A SINGULAR MISSION AND SPACE

THE MANY PERSPECTIVES OF HEALTH RESEARCH FIND COMMON GROUND IN A NEW HUB.

SEE PAGE 10

LEHIGH UNIVERSITY | P.C. ROSSIN COLLEGE OF ENGINEERING AND APPLIED SCIENCE

CONTENTS

Departments

ON THE COVER

Lehigh's new Health Research Hub is promoting camaraderie and serendipity while facilitating unexpected discoveries.

Features

resolve

A FOCUS ON LEHIGH ENGINEERING

VOLUME 1, 2014

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A fond farewell and a new challenge

Welcome to the 15th issue of* Resolve*, a magazine dedicated to research and educational innovation in the P.C. Rossin College of Engineering and Applied Science at Lehigh University.

It is with mixed feelings that I write to you for the last time in this space. I have been appointed provost and executive vice president of George Mason University in Fairfax, Virginia, and I will be leaving Lehigh this summer.

I am thrilled and excited to start the next phase of my career at George Mason. But I will miss Lehigh dearly. After almost three decades here, I owe my sincere gratitude to the mentors, colleagues, students and friends with whom I have worked side by side to build something truly special and distinctive. Together, I believe we have made a real and positive impact on the lives of young people.

The remarkable support from my colleagues has made it possible to work toward a bold vision—of engineering as Renaissance thinking for the era of technology, and of the engineer as Renaissance person for the 21st century.

This vision has grown out of trends that for several decades have been broadening engineering's role in society. Engineering is no longer a narrowly defined trade, but has become a way of thinking that benefits leaders and innovators broadly. An engineering education cultivates future leaders in business, law, medicine, architecture, design, journalism, public policy, environmental studies and, of course, engineering and innovation.

With the creativity and collaborative spirit of colleagues across the entire university, we have helped realize this vision and made it uniquely Lehigh:

• By establishing undergraduate interdisciplinary programs in bioengineering, computer science and business (CSB), integrated business and engineering (IBE), sustainable development, entrepreneurship and IDEAS—the integrated degree in engineering, arts and sciences;

• By launching professional master's degrees in analytical finance, structural engineering, healthcare systems engineering, energy systems engineering, and technical entrepreneurship;

• By expanding opportunities for undergraduate research with the Freed Undergraduate Research Symposium, with the Summer Research Fellowship program, and with a Clare Booth Luce Foundation grant for undergraduate women;

• And by improving the recruitment and retention of STEM women faculty with an NSF ADVANCE grant.

In addition, we have started multidisciplinary research initiatives in energy and infrastructure, in computing and data analytics, and, with help from an alliance with the Mayo Clinic, in health and healthcare delivery.

"Remarkable support from my colleagues has enabled us to work toward a bold vision of engineering as Renaissance thinking for the technology era." —S. David Wu

The main article in this issue (p. 10) discusses the new Health Research Hub in Iacocca Hall. The HRH represents an effort to promote the interdisciplinary collaboration that is vital to research while redefining how lab facilities are managed, allocated and shared. We hope it will set the tone for future space renovations throughout the university.

Several other articles in this issue are related to health research and healthcare. On page 22, you can read about Lehigh's Biosystems Dynamics Summer Institute, which teams faculty and students from biological science, engineering and other fields. The Q and A (p. 8) features Peter Linz, a member of the Engineering Advisory Council and a former Navy cardiologist who now works as a physician with the global charity Mercy Ships. And the Rising Star article (p. 24) features chemical engineer Bryan Berger and his work with doctors to combat the growing problem of drug-resistant bacteria.

I hope you enjoy this issue of *Resolve*. It has been an honor and privilege to work with you; I trust that our paths will cross in the future.

S. David Wu, *Dean and Iacocca Professor*
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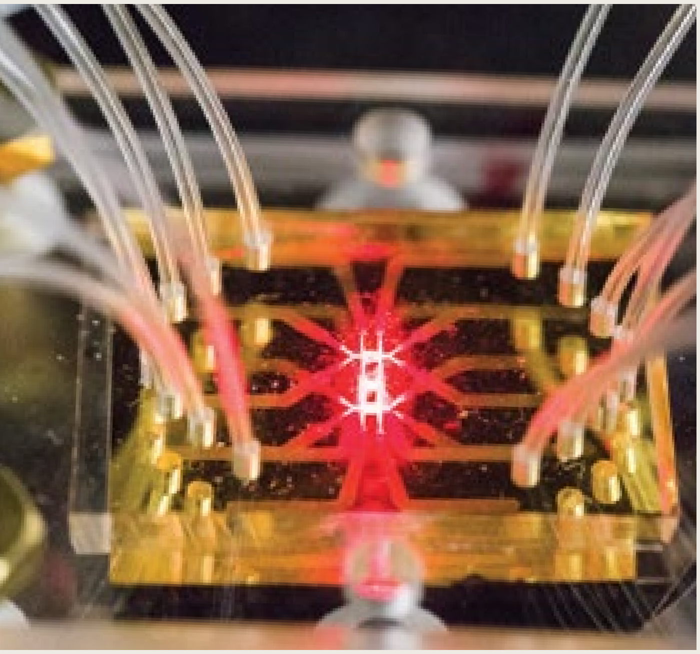
The profitable dance of light waves and electrons

Engineers improve the sensitivity of nanoplasmonic biosensors

By utilizing an electronic or optical system to detect and interact with the components of biological materials, biosensors make it possible to analyze DNA, measure blood glucose content and detect biotoxins in the water or atmosphere.



Yongkang Gao (right) and Filbert J. Bartoli took advantage of nanofabrication advances to improve the resolution of their nanoscale biosensors to levels almost as sensitive as those achieved by much larger commercial systems.

Yongkang Gao ’14 Ph.D. uses nanotechnology to improve the speed, efficiency and sensitivity of biosensors while dramatically decreasing their size and cost. His goal is to transform today’s surface plasmon resonance (SPR) biosensors, which take up most of a desktop, into nanoplasmonic biosensors that fit in the hand and perform hundreds of tests at a time.

Gao is the lead author on an article published recently in *Lab on a Chip*. “Plasmonic interferometric sensor arrays for high-performance label-free biomolecular detection” was coauthored with Ph.D. candidates Zheming Xin and Beibei Zeng, Prof. Xuanhong Cheng of materials science and engineering, Qiaoqiang Gan of SUNY-Buffalo and Filbert J. Bartoli, department chair of electrical and computer engineering and project leader.

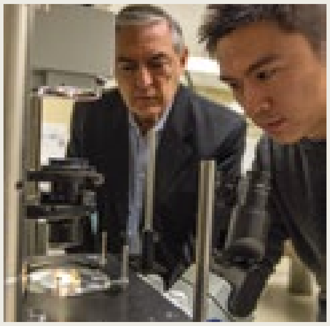
SPR technology represents the current “gold standard” for label-free biosensing, says Gao. SPR biosensors can monitor biomolecular bonding in real time while providing information on bonding kinetics, affinity, specificity and concentration, all without the use of labeling.

But the prism-coupling design used in most SPR biosensor systems, says Bartoli, requires complex and expensive instrumentation, limiting their use mainly to lab research applications.

Nanofabrication advances, says Gao, now make it possible to build, on a chip, nanostructures with dimensions similar to those of visible light waves, or about 400 to 700 nm. But while these devices are smaller, simpler and cheaper than conventional SPR biosensors, so far they are one to two orders of magnitude less sensitive.

By combining two new approaches—nanoplasmonic architectures and interferometry—the Lehigh group has retained the simplicity of nanoscale biosensors while improving sensor resolution to levels almost as sensitive as those achieved by commercial SPR systems.

Plasmonic architectures are based on surface plasmon polaritons (SPPs), a type of electromagnetic wave generated when a beam of light couples with an oscillating wave of electrons in the surface of a metal. Interferometry uses the interference of light waves to yield information about refractive index changes, surface irregularities and other phenomena involving the interaction of light and matter.



“The resonant interaction of light waves with oscillating electrons,” says Gao, “causes the waves to be highly confined to a metal surface. This creates a strong optical field within a nanoscale volume, which is especially suitable for biomolecular detection. The recent maturing of nanofabrication techniques makes it possible to exploit the plasmonic nanostructures to freely control the interactions between light waves and electrons.”

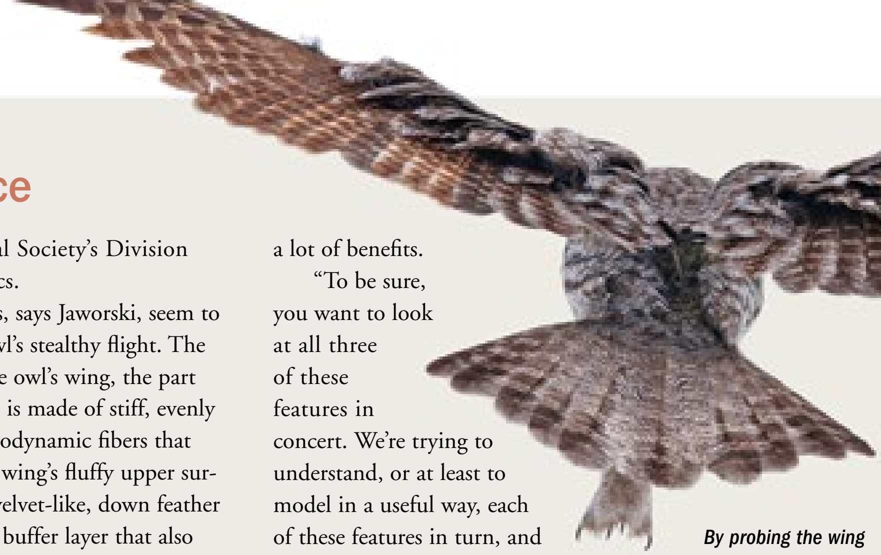
To improve the sensitivity of its nanoplasmonic sensing device, the Lehigh group is attempting to achieve a much narrower sensing peak line width, a higher spectral contrast and a larger peak shift for a moderate refractive index change.

After performing 3D numerical simulations to test and optimize various parameters, the group etched a 600-nm-diameter nanohole and three surrounding concentric grooves into a 300-nm-thick gold film. This geometry, says Gao, obtained greater sensitivity and imaging than nanohole array sensors developed by other researchers.

“Other researchers investigating nanoplasmonic sensors have been limited by a very broad line width,” he says. “We want a much narrower line width, as well as a high spectral contrast and an intense transmission peak.”

When the Lehigh researchers illuminated their device with a collimated white light beam, the light coupled with electrons in the concentric grooves to form SPPs, which propagated toward the nanohole in the center. There, the SPPs interfere with the light beam being transmitted through the hole.

“By careful structural tuning,” the researchers wrote in *Lab on a Chip*, “we can effectively control the phase and intensity properties of interfering SPPs and light waves to generate spectral fringes with high contrast, narrow line width and large amplitude, all key characteristics to achieve optimized spectral sensing.”



Engineered for stealth and silence

Harry Potter's snowy owl Hedwig delivers mail and provides companionship for the famous wizard. Owlman becomes a night-time vigilante when his younger brother, Batman, dies in the parallel universe created by DC Comics.

Perhaps the most intriguing owls, however, are the nonfictional ones. Large owls—the snowy, great horned and great gray—are a force to be reckoned with in the animal kingdom. They are silent hunters, unlike hawks and eagles, which depend on speed to catch prey.

Learning how these large birds swoop noiselessly, says Justin Jaworski, assistant professor of mechanical engineering and mechanics, may help engineers create quieter airplanes, wind turbines and underwater vehicles.

Jaworski began studying owl wings in 2011 with researchers at the University of Cambridge, where he was an NSF international research fellow. He presented his group's findings last year to the American Physical Society's Division of Fluid Dynamics.

Three features, says Jaworski, seem to account for the owl's stealthy flight. The leading edge of the owl's wing, the part closest to its head, is made of stiff, evenly spaced, mostly aerodynamic fibers that reduce noise. The wing's fluffy upper surface, a mesh of a velvet-like, down feather material, creates a buffer layer that also stifles sound.

The third and arguably most important feature of the wing is its porous and compliant trailing edge, where the most noise is generated. In contrast to the stiff feathers on the trailing edge of a duck or eagle wing, the trailing edge feathers on a large owl's wing are flexible and provide significant noise reduction.

"The trailing back edge is the predominant noise source for any blade that passes through the air—not only the owl, but also aircraft and wind turbines," says Jaworski. "If you can eliminate the noise there, you can have a lot of benefits.

"To be sure, you want to look at all three of these features in concert. We're trying to understand, or at least to model in a useful way, each of these features in turn, and see how they interact with each other."

Jaworski now works with researchers from Virginia Tech and Florida Atlantic University. The goal is to develop knowledge about noise suppression in owl wings into technologies that mitigate noise from turbine blades on windmill farms. One possibility is to add a porous and compliant extension to the back edge of a turbine blade. Another is to create a fuzzy upper surface.

"The final say in the owl problem," says Jaworski, "will be how to understand each of these wing elements, how to integrate them together, and how to apply what we know to engineering design."

By probing the wing features that enable large owls to swoop noiselessly, engineers hope to learn how to design quieter wind turbines and airplanes.

Poking information from molecules

Xiaohui (Frank) Zhang, assistant professor of mechanical engineering and mechanics, pokes single molecules and measures the force exerted. Learning how cells sense and respond to mechanical stimuli, he says, could improve the diagnosis and treatment of many diseases.

"The mechanical environment is important in growing organisms," says Zhang. "If you grow stem cells in a soft environment, you can easily differentiate them into neurons or liver cells, but if you grow them on a hard surface like a petri dish, you can grow bone. Somewhere in between, you grow muscles. This phenomenon is not completely understood."

Understanding the integrin molecule, which is found in almost every cell in the human body, could help shed light. Zhang's group uses atomic force microscopy, optical tweezers and a single-molecule force spectroscopic approach to manipulate and measure the mechanical forces exerted on integrin molecules. Their results show that integrin can indeed determine whether a surface is hard or soft.

Single-molecule measurement allows the team to exert minute, controllable forces onto micron-size polystyrene beads held by optical tweezers. They move the tweezers to apply force in various directions. How much force?

"About a pico newton," Zhang says. "That's about the amount of force ten million people would each have to exert to collectively hold a human hair."

The group is analyzing how stimuli applied to a cell membrane alter molecular shape and affect biochemical activities inside and outside the cell. They are also exploring how the VWF (Von Willebrand factor) blood glycoprotein begins to stretch out when a living being bleeds, and as it stretches, applies platelets to the injured site, thus initiating the healing process.

If they can learn how integrin becomes a "switch," as VWF does in blood, Zhang says, it may be possible to develop mechanically switchable devices made of polymer that would be injected into the body, remain inactive until they encounter a disease like cancer, and then release an anti-cancer drug.

The group will also observe how integrin, after being activated by mechanical stimuli, interacts with binding partners like ligands and other proteins. Their hope is that scientists will be able to manipulate integrin function by changing its force-sensing properties, which will help in diagnosing and treating integrin-related illnesses such as cancer, heart disease and multiple sclerosis.

The integrin research is funded by the American Heart Association.

A revolution, one layer at a time

Pearson (below) and Harmer are seeking to enhance the mechanical and electrical properties of powder-based polymers used in selective laser sintering, a rapid 3D printing method.

Much as the Internet has transformed commerce and communications, 3D printing, or additive manufacturing, may revolutionize industry by making it possible to make products in a home or office, rather than a factory.

A 3D printer produces an object by laying down successive layers of material in different shapes. 3D printing is now used to create lighter airplane parts, aerodynamic car bodies, custom prosthetic devices and more.

Martin Harmer and Ray Pearson, professors of materials science and engineering, are evaluating the use of ceramic nanoparticles to enhance the mechanical and electrical properties of powder-based polymers that are used in selective laser sintering (SLS), a rapid 3D printing method. They collaborate with Paramount, a Pennsylvania company, to improve plastic parts made with 3D printing. The project is funded by the Research for Advanced Manufacturing in Pennsylvania program (RAMP).

Most methods of feeding material into a 3D printer create products that are strong from front to back (X axis) and from side to side (Y axis). In making the sole of a sneaker, however, weakness in the Z axis (top-to-bottom) causes the layer-by-layer technique to result in a weaker sole than a sole made conventionally.

An SLS machine uses a pulsed laser to fuse powdered material into 3D shapes. This allows the powder to be preheated, which produces denser material. Another advantage is that it does not require molds or other support structures because the product being made is surrounded by unsintered powder.

SLS can be scaled up to produce large parts, but a limited number of materials can be used in the SLS process. One—the polymer Nylon 12—has attractive mechanical properties, but its applications are limited by poor thermal and electrical conductivity.

In their experiments with Nylon 12, Harmer and Pearson add nanoparticles of silica and zinc oxide to the polymer using a slurry process. One challenge they face is achieving solid binding of the two materials at the surface.

"Our hypothesis is that this ceramic-coated polymer powder will absorb and retain more of the laser's heat and thus allow for improved sintering," says Pearson, who directs Lehigh's Center for Polymer Science and Engineering. "Our goal is to develop nanocomposite materials that will exhibit improved mechanical, thermal and electrical performance."

Undergraduates are learning to make materials atomistically in Lehigh's new Genome Accelerated Materials Evolution (GAME) Lab, which is adjacent to a 3D printing facility.

"Students will be able to integrate computer modeling with rapid processing to develop materials more quickly," says Harmer.

This October, Lehigh will host its ninth annual SPE Polymer Nanocomposites Conference.

Connecting fractures to impurities

Richard P. Vinci and his group are testing the toughness of very small amounts of metal and ceramics and finding some surprising insights.

Their work in damage-resistant transparent ceramics could lead to improved windows for spacecraft. And designers of automobiles and structures can benefit from learning why certain impurities cause brittleness and fracture at the grain boundaries of some metals and ceramics.

Just a few parts per million of an impurity, says Vinci, professor of materials science and engineering, can weaken a steel beam. "Exactly why it happens continues to elude us. Figuring this out is what our work is focused on."

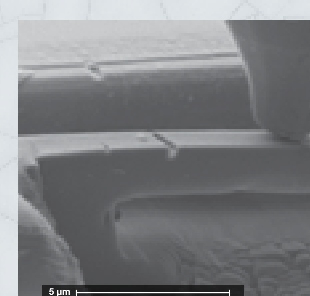
Vinci's group is studying spinel, a class of ceramics with promising military and aerospace applications, such as blast-proof windows. Spinel windows can be affordably made by adding lithium fluoride during manufacturing. But the compound migrates to the grain boundaries and weakens the spinel, obligating companies to use a more expensive fabrication process.

By conducting atomic-scale studies, Vinci's group hopes to learn why lithium fluoride causes brittleness. They are also experimenting with ytterbium, which migrates to grain boundaries but strengthens the spinel. They are using Lehigh's scanning and transmission electron microscopy (SEM and TEM) facilities to determine why this strengthening occurs.

The group also studies copper tainted with bismuth, an impurity that occurs in copper ore and can also appear when metals are mixed during recycling. In tests conducted on single grain boundaries with an SEM Picoindenter, the researchers have found that only certain boundaries are problems. They are attempting to pinpoint the culprits.

The Picoindenter, developed by Hysitron, a manufacturer of nanomechanical testing instruments, applies tiny forces to an object inside an SEM while measuring the force and the amount of deformation it causes. Hysitron chose Lehigh as the beta site to test the Picoindenter, which is the first device of its kind.

The project is supported by NSF and the Office of Naval Research. Collaborators include Profs. Martin Harmer and Masashi Watanabe and research scientist Animesh Kundu.



A Picoindenter/SEM image of a tiny notch engraved on a spinel cantilever.

Crossing the threshold for laser cooling

Group engineers gallium nitride to reverse light's tendency to heat the material through which it passes.

Gallium nitride has emerged as one of the most widely used materials in the optoelectronics industry and the most important semiconducting material after silicon.

GaN's hardness, crystalline structure and wide bandgap make it ideal for a variety of applications. These include light-emitting diodes (LEDs), laser diodes that read blu-ray discs, transistors that operate at high temperatures, solar cell arrays for satellites, biochemical sensors and electronic implants in humans.

Yujie Ding, professor of electrical and computer engineering, sees another, potentially more revolutionary role for GaN.

The compound, he says, can be engineered so that light passing through GaN actually cools it instead of heating it. This phenomenon, called laser cooling, or laser refrigeration, would eliminate the need for costly heat-dispersion methods that are employed to prevent electronic devices from overheating.

"GaN can be used to make lasers, optoelectronic and electronic devices," says Ding. "What if we could also use GaN for cooling? This would be one-stop shopping. We could monolithically integrate everything—the laser, the laser-cooling device and the electronic devices—on the same substrate."

Ding's group has reached the threshold for achieving laser refrigeration by utilizing anti-Stokes photoluminescence (ASPL), which refers to the tiny fraction of photons whose frequency increases after striking a material. Stokes scattering occurs when the frequency of scattered photons is lower than the frequency of incident photons.

The ratio of the occurrence of Stokes to anti-Stokes scattering, says Ding, is typically 35:1. Scientists would like to reduce this to 1:1, at which point a material neither heats nor cools when struck by light, and even further, when, with more anti-Stokes than Stokes scattering, a material imparts its energy, and thus its heat, to the light passing through it.

Two years ago, Ding and Jacob B. Khurgin, professor of electrical and computer engineering at Johns Hopkins, reduced the ratio of Stokes to anti-Stokes to 2:1 in GaN, in numerical simulations and in lab experiments. The ratio was the most favorable achieved to that point.

Recently, they improved upon their results and recorded a ratio of 1:4.

"We have not yet demonstrated cooling," says Ding. "That will require further work. But we have demonstrated that we are above the threshold for laser cooling."

Laser cooling was first demonstrated 20 years ago on glass doped with a rare earth element. This method is ineffective, says Ding, because only the relatively small portion of the material that is doped contributes to cooling.

GaN's crystalline structure makes it possible for a much larger portion of the compound to play a role in cooling. Of critical importance are the phonons, or collective vibrations at a uniform frequency, of the GaN molecules in the compound's crystalline lattice.

"Because of the nonlinear properties of the lattices," says Ding, "phonons vibrating at very high frequency break down to lower-frequency vibrations. At this lower acoustical vibrational frequency, the phonons become heat."

To prevent the breakdown of phononic vibrations, Ding's group combines the higher-frequency-vibration phonons with incoming photons. In this manner, the high-frequency phononic vibrations are removed before they break down, and the vibrations, instead of generating heat, are emitted as high-frequency photons.

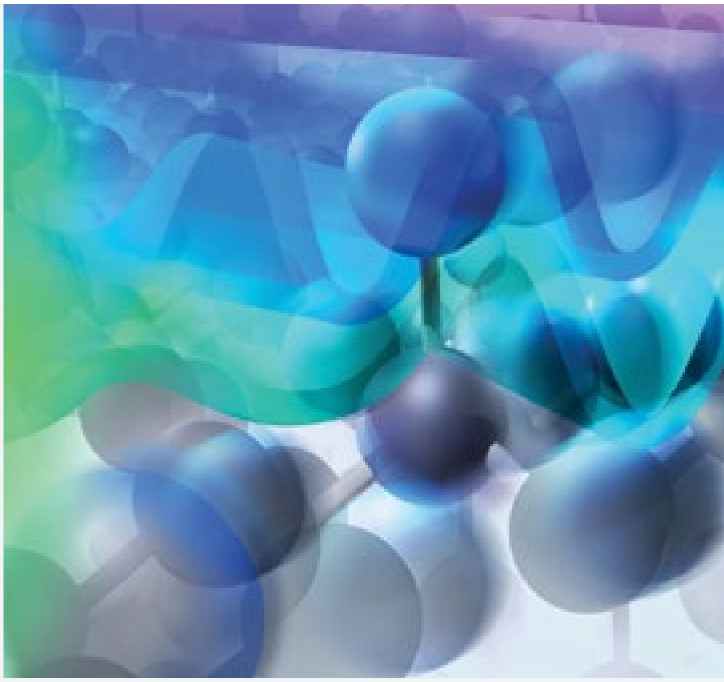
"The advantage of GaN," says Ding, "is that the collective vibration of all the GaN molecules in the lattice makes it possible for the entire lattice to potentially contribute to cooling by promoting the upconversion of high-frequency phonons.

"We have learned how to use ASPL to convert input photons with low energy to outgoing photons with higher energy. To do this, we remove phonons by using resonance enhancement of outgoing photons' energy with energy states of GaN. Thus we enhance ASPL.

"This is the best way to achieve laser cooling, because once the breakdown of high-frequency phonons occurs and produces heat, the process is not reversible. You have to work to remove heat and this is never effective.

"Ours can be considered as a fundamental breakthrough in laser refrigeration because it shows that laser refrigeration can be obtained with a III-V semiconductor, that is, with the very materials from which the optoelectronic devices that require cooling are themselves made."

The project is funded by Darpa. Ding's other Lehigh collaborators include Guan Sun '13 Ph.D. and Ruolin Chen, a Ph.D. candidate.



Incoming photons, says Ding, serve to remove high-frequency phononic vibrations before they break down and generate heat.

"We have learned how to use ASPL to convert input photons with low energy to outgoing photons with higher energy." —Yujie Ding

A diversity of data strengthens the versatile algorithm

Computer algorithms are being taught to interpret a variety of documents ranging from engineering journals to printed logs found in Iraqi police stations. But the quality of these computational tech-

The documents scanned by Bruno and Lopresti range from engineering drawings to photographs to handwritten notes.

niques is limited by the amount and diversity of data used to train them, says Daniel Lopresti, department chair of computer science and engineering.

"Machine learning is based on the assumption that we can develop algorithms that approach a human level of understanding," Lopresti says. "But because data sets are limited, we spend a lot of time focused on a tiny portion of the problem space."

Enormous amounts of data are needed to train and test document recognition algorithms, yet many researchers rely on well-worn data sets, such as a collection of IEEE journals scanned in the early 1990s, or handwritten exemplars scribed by students.

That may change thanks to the tens of thousands of documents that Lopresti and his students have rescued from the former Bethlehem Steel labs and offices on the Mountaintop Campus that were recently acquired by Lehigh. This historic corpus includes routine reports, such as a binder that chronicles all the materials used in the blast furnaces for decades, as well as thousands of engineering drawings—"everything from drawings of tiny parts to floor plans for entire facilities," says Lopresti.

"Some of the Bethlehem Steel offices were pristine," says Barri Bruno, a senior who inherited the task of organizing and starting to scan more than 35 large filing boxes of papers and hundreds of tubes of drawings.

"Other offices looked like the apocalypse had just happened. Personal papers and coffee cups were left lying around as if people had left on a Friday and never returned."

Working with Lehigh librarians, Lopresti's team had just weeks to plan, and mere days to capture and cart away, a small portion of the documents abandoned in the labs. The scenario resembled the research project that Lopresti recently conducted for the Defense Advanced Research Projects Agency (DARPA), in which researchers used documents rescued from police stations in Iraq to improve the machine recognition of Arabic handwriting.

To date, Bruno has scanned more than 30,000 Bethlehem Steel documents, including handwritten logs, computer printouts, letters and notes. She estimates she is less than 20 percent of the way through the materials.

When researchers continuously use known, homogeneous data to develop algorithms, these algorithms may be tuned for that data but will not work well in the real world. Lehigh's Bethlehem Steel collection, which Lopresti hopes can be released to researchers in the near future, offers something for researchers working on diverse problems.

"Printed documents may be interesting to one researcher, and handwritten documents to another," Bruno says. "Because this is such a large collection and it is not synthetic"—it wasn't created by researchers or scanned from a single source—"it becomes much more useful."

In addition to making high-resolution scans, Bruno has been developing what researchers call the "ground-truth" for the collection. She is painstakingly creating an inventory of the documents, noting which portions of each page are printed texts, tables, handwritten notes, photographs or other content, so that researchers will have a benchmark to test their algorithms against. She has described the process in a paper that was presented at the 21st Document Recognition and Retrieval Conference in San Francisco in February.

"We have a long way to go," Bruno says. The documents have to be checked for personal information, such as Social Security numbers, and Lopresti is working with attorneys for Lehigh and ArcelorMittal, which owns the assets of the former Bethlehem Steel, to avoid copyright concerns. If researchers can't share the documents they work with so other academics can verify their work, then the documents are not useful for developing algorithms, Lopresti says.

But if all goes well, scientists designing new ways for computers to interpret printed and handwritten documents will soon have a treasure trove of data left for them by workers in the offices and labs at Bethlehem Steel.

Researchers achieve peak performance with advanced sensor systems

Geotechnical engineers obtain more accurate picture of impact from projectiles.

The innovative use of advanced sensor systems, says Sibel Pamukcu, could enhance the protection provided by soldier's helmets and armor and also help locate pipeline leaks and other underground events.

Fiber-Bragg Grating (FBG) sensors are used routinely to measure strain, temperature and other environmental factors, says Pamukcu, professor of geotechnical engineering in the department of civil and environmental engineering. The sensors do this by detecting subtle changes in light refraction within the fibers.

Pamukcu and researcher Qingsong Cui have tuned FBG sensors to help provide more accurate measurements of the forces transmitted when a projectile strikes a soldier's helmet.

Even when tests show that armor prevents a projectile from penetrating, says Pamukcu, researchers have found that soldiers can still suffer internal injuries.

"The projectile impact creates powerful force fields that are very fast, measured in microseconds, and that travel over very short distances," says Pamukcu. Current testing methods may not pinpoint those forces because they capture average impact forces, not peaks.

Cui has tuned FBG sensors to resolve events as short as 20 microseconds, while Pamukcu has designed a prototype sensor system that has the potential to accurately measure the size and velocity of stresses a person experiences from projectile impact. The researchers embedded an array of sensors inside a form made of ballistic clay, which mimics the consistency of the human body, and tested a variety of impacts.

"The whole event takes only 400 microseconds," says Pamukcu. "In the spatial resolution that we attempted, we were able to capture the peak strains that other sensors might miss."

Pamukcu also works with Prof. Liang Cheng of computer science and engineering to improve the ability of underground wireless sensors to detect subsidence, or the infiltration of contaminants from a fracking well or pipeline leak. They have developed a method of measuring changes in the attenuation of underground radio signals to determine that a geo-hazard event has occurred.

Pamukcu and students Erinn Bonshak, Scott Cohen and Kepha Abongo test projectile impacts on clay embedded with sensors.

"We're talking about long distances and very spread-out applications," Pamukcu says. Wireless sensors can be placed along the length of a pipeline, for example. Rather than testing for oil or gas at many points along the pipeline, they have set up wireless sensors to detect changes in the transmission between two sensors along the line.

"If we get oil or gas coming through (between sensors), the dielectric constant and the electrical conductivity of the ground will change and the baseline attenuation will change," Pamukcu says. "When we have these sudden changes, we can say there may be something going on, and then we can apply more precise diagnostic sensing in that area."

The wireless sensors can also be tuned to detect signal fluctuations that result from changes in the mass density of the ground between sensors, says Pamukcu. This can provide early detection for potential leaks.

Pamukcu gave a keynote lecture titled "Geosensing for Developing Sustainable Responses to Environmental Hazards Underground" at ASCE's GeoCongress 2014 in Atlanta in February.

A top honor from UEDA

Lehigh's Master's of Technical Entrepreneurship (MTE) program was recently honored by the University Economic Development Association (UEDA) as the best such program in North America for talent development.

The honor—the fourth award Lehigh has received from the UEDA—came after a team of faculty members made a presentation about the MTE program at UEDA's annual summit in Pittsburgh.

The 12-month graduate program trains students to create startups and bring new products and services to market. It is offered by the P.C. Rossin College of Engineering and Applied Science and the Baker Institute for Entrepreneurship, Creativity and Innovation.

UEDA, a national organization of more than 100 universities and their economic development affiliates, encourages economic development by promoting innovation, entrepreneurship and higher education partnerships.

UEDA gave 2013 Awards for Excellence in six categories at its summit. The Talent Development category recognized initiatives that promote the development of 21st-century skills. Projects were judged on originality, sustainability, scalability and ability to be replicated.

The MTE program has grown rapidly. Its first contingent of 14 students completed the program in May 2013. Within three months, six students had started their own businesses and seven had taken jobs in industry or academia. In May 2013, 28 more students enrolled in the program.

MTE is looking to double its enrollment again by 2015, said program director John Ochs.

"We believe that student innovation, fueled by creativity, is this generation's most important economic development engine," said Ochs, a professor of mechanical engineering and mechanics.

INTERVIEW BY **WILLIAM TAVANI**

ON BOARD THE AFRICA MERCY

A VITAL ROLE FOR ENGINEERS IN HUMANITARIAN HEALTHCARE

Peter E. Linz, a renowned researcher in hypertension, lipid management and atrial fibrillation, has participated in many multicenter clinical trials and multinational studies, including several for the National Institutes of Health. In 2011, Dr. Linz retired from the U.S. Navy after a 30-year career as a cardiologist. Since then, he has worked as a physician with Mercy Ships, a global charity that operates hospital ships in developing countries. He is also associate professor of medicine at the Uniformed Services University in Bethesda, Md., where he earned his doctor of medicine degree. He sits on the dean's advisory council of the P.C. Rossin College of Engineering and Applied Science, and his son Thomas is a member of the college's Class of 2014.

Q: ***You are renowned for your research in hypertension, lipid management and atrial fibrillation. What are some of the discoveries you have made in these areas?***

A: I took part in major National Institutes of Health studies that examined the best strategies to treat these conditions, given the medicines we have. They included ALLHAT, a study over more than 10 years of the best combination of medications for hypertension; AFFIRM, an atrial fibrillation study on heart rhythm versus rate control; and ACCORD, which looked at the best strategy to control cardiovascular risk in diabetes patients.

Those studies were pivotal in developing guidelines for treating these conditions. For example, ACCORD, one of the largest NIH studies ever funded, looked at glucose control, high blood pressure and cholesterol. All three parts of the study showed that less intensive therapy was better than more intensive treatment. That has important implications for treatment, safety and costs. Doctors follow the guidelines from those studies today. That gives me a sense of satisfaction.

Q: ***What kind of changes do you foresee in the ways in which these conditions are treated?***

A: For atrial fibrillation, one newer treatment is ablation, an invasive procedure in which electrophysiologists try to eliminate the condition mechanically. There's controversy about who should have that procedure and the risks involved. We're trying to figure out the best strategy.

Q: ***How did you first get involved in humanitarian healthcare?***

A: One of the highlights of my career with the Navy was in the planning and leadership of a

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humanitarian healthcare mission in Southeast Asia with the U.S. Navy hospital ship, the USNS Mercy. I spent a year with the mission. We went to the Philippines, Vietnam, East Timor, Papua New Guinea and Micronesia. We had contact with more than 90,000 patients in six months.

Q: ***What inspired you to join Mercy Ships after you retired from the U.S. Navy in 2011?***
A: My work with the USNS Mercy ignited a passion in me. Mercy Ships was a natural fit. My wife has known about the organization for about 20 years. It was through her that I got involved.

Q: ***What countries have you had the opportunity to visit with Mercy Ships?***
A: I've been to Togo, Guinea and Congo. Mercy Ships works primarily in countries that lie within 15 degrees north and 15 degrees south latitude in Africa, from Senegal in the north to Angola in the south. The U.N. has a Human Development Index, or HDI, that measures life expectancy, infant mortality, educational opportunities and resources. Many countries in the bottom 15 or 20 percent of the HDI are located in that part of West Africa. That's why Mercy Ships works there.

Q: ***What kinds of work have you done in these countries?***
A: The ship ties up at a location for 10 months and provides oral surgery, plastic surgery, burn reconstruction, eye surgery, cataract surgery, pediatric orthopedics and general surgery. We also have an active dental program. The last time we were in Guinea, we extracted 35,000 teeth and also performed more than 2,800 surgical procedures in a 10-month period.

Q: ***What kind of impact has this work had on you, personally?***
A: I spend a couple months each year aboard the ship, and find it incredibly rewarding. It's a great way of giving back and demonstrating one's Christian faith. But it's hard work. When the ship arrives at a country, we have a patient selection day. We might see 5,000 people in line for evaluation. The number of people who need care and whom we screen is greater than the number we can care for. That can be emotionally draining, so we try to do the most good for the biggest number of people.

Q: ***How can engineers help improve healthcare and its delivery?***
A: Some of the solutions needed for healthcare in the developing world go right to engineering skills. These include infrastructure, access to clean water, proper sanitation and reliable electricity. Also, we now have solar power batteries for the equipment that refrigerates vaccines. And cell phones are everywhere. The development of hand-held, smart-phone-based diagnostic aids has a huge potential for portable, easy-to-maintain diagnostic applications. One smart-phone application can take a picture of someone's eye and diagnose a cataract. Another records an EKG and transmits it wirelessly. These sorts of applications have potential for huge impact in terms of portability and affordability, as well as the development of tele-medicine to do long-distance diagnosis in remote areas with a limited number of physicians.

Q: ***How have you interacted with engineers during your career?***
A: I've dealt mostly with people in the medical device industry, engineers making things like pacemakers, defibrillators and cardiac catheterization labs. Plus, I've worked with people who develop the IT interface between medical devices on the one hand and medical records or medical imaging on the other, for better interpretation and documentation.

At Mercy Ships, we work with a group called Engineering Ministries International. They do an assessment of a local hospital and develop a plan to meet its infrastructure needs, everything from water to waste management to maintenance needs. On the ship, we have maritime engineers to keep the ship running, and we train biomedical repair technicians to maintain medical equipment. We also work with engineers on the automation of laboratory diagnostic equipment.

Q: ***What kinds of changes do you foresee in engineering education?***
A: I see a need for solutions that help integrate the greatly increasing amount of information. I also see a trend toward more multidisciplinary education between engineering and other fields, and toward increased specialization.

Q: ***What can we do to improve the teaching of STEM subjects and increase the numbers of engineers and scientists in the U.S.?***
A: I think it's a matter of exposure and getting people excited about science. That comes from excellent teachers and mentors who share their excitement.

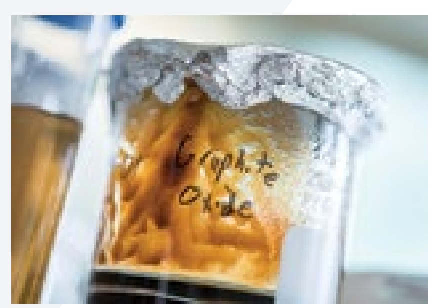
Q: ***What has been the most memorable accomplishment in your career?***
A: Two things stand out. First, I was involved in medical education for years. At the Naval hospital in San Diego, I ran the cardiology training program for about seven years, and I chaired the internal medicine department and supervised its training program for 2.5 years. I was fortunate enough to educate and mentor a generation of cardiologists.

Second, being involved in humanitarian work has been life-changing. You can be overwhelmed by the sheer numbers of people who need help. But the reward comes with the individual. Watching someone get their vision back after being blinded by cataracts for years, or someone who is cured from a large facial tumor, is deeply rewarding. There are a thousand stories out there. In the end it comes down to individual relationships. If you take the problems one at a time, you can have a victory in each one.

> “Lehigh’s project—more than any other we’ve done—really brings together what are often distinct disciplines into a single mission and space.”
>
> —Robert Nalls, *principal architect, Nalls Architecture Inc.*

MANY PERSPECTIVES, A SINGULAR

NEW HEALTH RESEARCH HUB IS A CENTER FOR CAMARADERIE



STORY BY
RICHARD LALIBERTE

PHOTOGRAPHY BY
RYAN HULVAT

If they were asked to name the key ingredients for promoting scientific and technological innovation, many people might point to hard assets like lab benches, specialized facilities and equipment.

But as research becomes increasingly interdisciplinary, making collaboration ever more necessary, another view is gaining popularity. It suggests that inspiration often arises from catalysts like coffee and conversation, rubbing elbows with colleagues and simply hanging out.

All of these factors are integral to the design and function of Lehigh’s new $4.5 million Health Research Hub (HRH), which opened in late 2013 in Iacocca Hall on the Mountaintop Campus.

“HRH is intended and designed, from an architectural perspective, to be a truly collaborative space in every sense of the word,” says Anand Jagota, professor of chemical engineering and director of the bioengineering and life sciences program. “We’re redefining how facilities are laid out, how they’re allocated and how they’re shared.”

The renovated 4,500-square-foot space immediately conveys a feeling different from that of many other Lehigh

MISSION

research facilities. Rather than being walled off from each other, labs are open and bright, with long, barrier-free benches that allow easy interaction between researchers working on different projects or in different disciplines.

The HRH, says Jagota, accommodates three core functions that rarely exist side by side: cell culture, characterization using optical microscopy and other forms of imaging, and microfabrication for engineering biological systems and devices.

Perhaps most noteworthy, a conference room adjoins an area of student desk space at the heart of the Hub.

"There's always a natural inclination to put in more labs," says Jagota. "But we chose to set aside almost 500 square feet for a place in the middle of the facility where people can exchange ideas, call something up on a computer or just sit down and talk. The idea is to encourage people to work across departments and provide the spark for new projects."

Indeed, says S. David Wu, Iacocca Professor and dean of the P.C. Rossin College of Engineering and Applied Science, the HRH will set the tone for future space renovations throughout the college.

"The HRH is meant to be a showcase that demonstrates new concepts and best practices in research collaboration," says Wu. "In its physical layout, its management and the manner in which its space is allocated and reallocated, the facility will encourage multidisciplinary collaboration."

AN UNEXPECTED USE FOR A PATHOGEN

A case in point is the partnership between Bryan Berger and Steve McIntosh. While both have positions in the department of chemical engineering, "our research areas are as different scientifically as two people's can be," says Berger. But because they had socialized, Berger thought of McIntosh while he was working with the Lehigh Valley Health Network to study pathogenic bacteria that grow on inert surfaces.

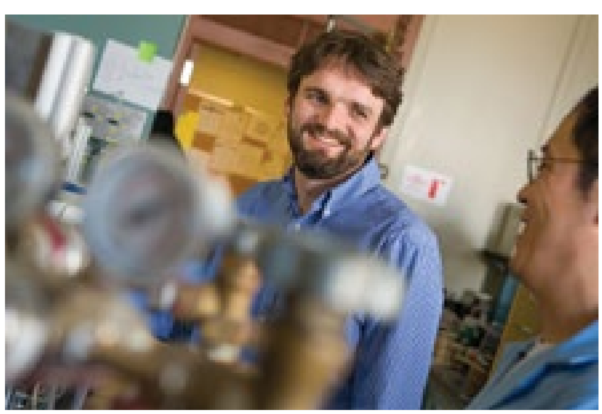
"These bacteria essentially chew up metal and spit it out as nanoparticles," Berger says. What if that process could be reengineered to harness the bacteria to make nanoparticles of specific metals? Doing so could produce semiconductor particles called quantum dots that could be used in diverse applications for wide-ranging fields including healthcare, consumer goods—and renewable sources of energy.

"Steve had the knowledge to integrate quantum dots into a device to make methanol," Berger says.

Joining forces with Chris Kiely, professor of materials science and engineering, and Robert Skibbens, associate professor of biological sciences in Lehigh's College of Arts and Sciences, the team secured a $2 million grant from the National Science Foundation to develop a biological process for generating renewable methanol fuel. The team is combining quantum dots with enzymes to capture the energy in sunlight and separate hydrogen and



McIntosh and Berger, the first group to move to the HRH, are working with two other researchers to develop a biological process for generating methanol fuel.



carbon from, respectively, water and carbon dioxide to form a hydrocarbon.

"Typically this is done with nasty solvents and reactants on a small scale," McIntosh says. "Harnessing a biological process allows us to do it greener, at low cost and on a much larger scale."

Berger and McIntosh were the first multidisciplinary team to set up shop in the Health Research Hub.

"It helps promote collaboration to have a sense of working with your friends or people you run into every day," McIntosh says. He and Berger had developed that familiarity randomly before the HRH took shape, he adds, but "with the Hub's shared space, this should happen more frequently."

"A NATURAL INFLUX"

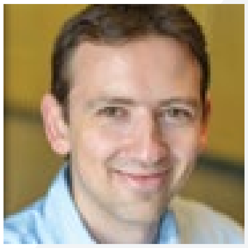
The concepts behind the HRH grew out of a greater vision for the future of both the bioengineering program and Lehigh as a whole.

"Health-related research has been growing at Lehigh as part of a natural influx of biology into the physical sciences and engineering in general," says Jagota. "It's a major area of the economy that grew even through the recession—and will continue to grow over the next several decades."

Recognizing these trends, Lehigh launched an undergraduate bioengineering program in 2002. "When that program acquired some maturity, we set out to decide what we needed to do and what we should provide for new faculty in order to develop a strong research identity," Jagota says.

That required a careful evaluation of Lehigh's attributes. Lehigh's relatively small size and its lack of a medical school, says Jagota, ruled out conducting research on heart transplants, for example, or in an area that required testing on large animals or access to certain kinds of tissue samples.

"We looked at our strengths in materials, devices and engineering," Jagota says. "The combination of these strengths informed the kind of technology- and engineering-centric health research we think is going to succeed at Lehigh."



"It's not typical to have optical engineering space in close proximity to the tissue culture lab, **but we have that in the HRH.**"

—Yevgeny Berdichevsky

Part of the vision behind the HRH included encouraging collaboration among people with disparate expertise in what is becoming an inherently multidisciplinary field. "The question became, 'What kind of a facility do we need to build to support that?'" says Jagota.

"A SINGLE MISSION AND SPACE"

Robert Nalls is principal architect with Nalls Architecture Inc. of Narberth, Pa., near Philadelphia, which specializes in buildings that support scientific research for institutional clients. The firm has completed a variety of projects, creating designs for the University of Pennsylvania's new Vaccine Research Institute in Guangzhou, China, and for the renovations of Princeton's Campus Club and of the biomedical labs at the University of Virginia's Medical School.

"We've worked on other projects that entail interdisciplinary collaboration," Nalls says. "But Lehigh's project—more than any other we've done—really brings together distinct disciplines into a single mission and space."

The characterization lab on the south side of a central corridor features three darkened, windowless rooms to enhance visualization for microscopy and imaging. On the north side of the hall, the fabrication and cell culture labs sit side by side. Both are pressurized, with access through air locks. The pressure in the fabrication lab is designed to push against outside air to keep the room clean, while the pressure in the tissue lab directs airflow the opposite way to keep potential contaminants inside the room.

"The tissue lab exceeds biosafety level 2 standards, making it the highest biosafety level lab at Lehigh," says Xuanhong Cheng, associate professor of materials science and engineering. "These kinds of rooms can be a challenge in a renovation," Nalls says. "Supporting mechanical systems become very important for design and construction."

Both the fabrication and tissue labs use smart systems that gather information about air pressure and handling to constantly maintain proper relationships between adjacent spaces, says HRH lab manager Guowei "Will" Xia.

The conference room and student desk area perform a safety function while promoting collaboration.

"It's not safe or appropriate to bring food or coffee into labs that may have chemical or biological hazards," Nalls says. "That's another reason it's so important to have a dedicated non-lab environment to come together and eat lunch, have meetings or talk about what you're discovering."

Flexibility was a key consideration throughout the space, especially in bench labs.

"You can unplug equipment from the ceiling and take it to another lab, or make room for other equipment so the lab can change as the science or project needs change," Nalls says. Some equipment will be built or brought in by faculty. Other equipment will be provided through research grants or funds allocated from an internal Lehigh award supporting work at the HRH.

Flexibility will allow different research teams to rotate in and out of HRH space, says Jagota. Thus, space in the facility will be assigned on a year-to-year basis, and research teams must reapply for renewal at the end of each year.

"One of our tasks was to come up with a process for systematically inviting proposals for the space," he says. "We're explicitly looking to bring people together for new multidisciplinary projects that would otherwise not be able to get off the ground."

PROBING NEURON DEATH WITH OCM

Yevgeny Berdichevsky and Chao Zhou study epilepsy by using brain tissue cultures and microelectronics to observe how seizures affect neurons. Both are assistant professors of electrical and computer engineering, but until recently their laboratories were located two miles from each other.

"Before HRH, I was at the Mountaintop campus and Chao was on the main campus," says Berdichevsky. "To conduct our research, graduate students carrying tissue samples would often have to drive back and forth between the two locations, which is far from ideal."

In their project, Berdichevsky and Zhou are attempting to gain a better understanding of the neuron death that occurs during epileptic seizures in order to promote the development of new anticonvulsive drugs.

"About 30 to 35 percent of people with epilepsy don't respond to medication," Berdichevsky says. "The next step for them is neurosurgery."

Zhou has developed optical coherence microscopy (OCM) technology that enables high-resolution imaging of brain cultures.

"Having windowless darkrooms where light can't intrude is critical for optical imaging," Berdichevsky says, "and so is having optical engineering space in close proximity to the tissue cultures. It's not typical to find those two things together, but we have that in the HRH."

The success of the project, he adds, depends on two different areas of expertise coming together.

"Each of us brings something to the table that the other doesn't have. Together, we can build a better project than either of us could do alone."

The HRH offers similar advantages to Yaling Liu, associate professor of mechanical engineering and mechanics and also a faculty member in the bioengineering program. Liu has teamed with Daniel Ou-Yang, professor of physics, and Linda Lowe-Krentz, professor of biological sciences, both in the College of Arts and Sciences, to develop fast, low-cost methods for testing anti-cancer drugs. With funding from the National Institutes of Health, the team is conducting tests on a chip etched with channels that are coated with human endothelial cells to mimic the capillaries of the human lung.

Liu examines interfacial phenomena at the nanoscale while Lowe-Krentz studies how blood flow changes cell behavior. Ou-Yang is developing observational tools using technologies such as confocal and scanning electron microscopy.

"My lab, the confocal scanning microscope and the scanning electron microscope were all in different places," Liu says. "Transporting live samples back and forth sometimes damaged them. Having a core centralized facility is very helpful."

"The Hub is a beautiful space that shows Lehigh is committed to collaborative biomedical and biological research."

—Angela Brown

A FOCUS ON PROTEIN TRANSPORT

Liu is also working with Cheng on a microchip designed to isolate cells that tumors shed into the bloodstream in hopes of developing better diagnostic tests. "Her lab is in Iacocca and mine is on the main campus," Liu says. "It will be easier to have all our efforts in one location."

Angela Brown, assistant professor of chemical engineering, joined the Lehigh faculty in January and has already set up an HRH lab to study alternatives to existing antibiotics that bacteria increasingly resist.

"Rather than focusing on killing bacteria, I'm focused on the toxins that bacteria produce and how these toxins interact with human cells to cause disease," says Brown.

Brown is particularly interested in the outer membrane vesicles that allow bacteria to secrete toxins and deliver them to other cells. Understanding the mechanisms that bacteria use to transport proteins could help scientists develop new weapons against pathogens and also improve the delivery of some medications.

In the HRH, Brown will utilize the microscopy facilities and culture lab to grow both bacterial and human cells.

"The Hub is a beautiful space that shows Lehigh is committed to collaborative biomedical and biological research," says Brown. "When I interviewed here, I noticed that people collaborate across departments. It's not just something the administration encourages; it's something people actively do."

In just its first few months, says McIntosh, the HRH has made collaboration easier.

"I've seen it often in the shared conference space, the student spaces and the bench areas," he says. "I'll be involved with a discussion with one student, and another who is working nearby chimes in.

"A camaraderie is developing where we help each other out more."

WHEN IMAGES ALONE CAN'T TELL THE WHOLE STORY

A chemical engineer shares mathematical insights with doctors and biologists.

If a picture is worth a thousand words, says William Schiesser, then the right mathematical equation, in today's Information Age, can be worth a thousand pictures.

This modern twist on an old saying is making the rounds among the mathematicians and engineers who use numerical models to gain a clearer, more detailed picture of the physical world.

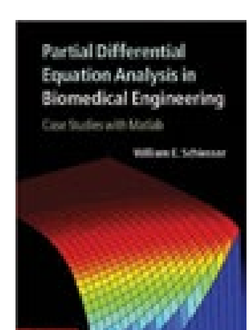
These researchers, says Schiesser, the R.L. McCann Professor Emeritus of Engineering and Mathematics in the department of chemical engineering, are making critical contributions to the field of biomedical engineering.

CT scans, MRIs and other computer imaging tools have improved the scope and accuracy of medical diagnosis by generating huge quantities of data that provide new insights into the physiology of the human body.

But analyzing endless streams of data can be a daunting task for human beings, says Schiesser.

"How do we interpret data when it can be overwhelming? We use mathematical models based on differential equations. With the right software, computers can analyze huge streams of data and detect patterns and other things that human beings can't."

Schiesser is the author of *Partial Differential Equation Analysis in Biomedical Engineering: Case Studies with Matlab*, published in 2012 by Cambridge University Press. Two more books, his 12th and 13th, were published in March by John Wiley & Sons Inc.—*Differential Equation Analysis in Biomedical Science* and *Engineering: Ordinary Differential Equation Applications with R* and *Differential Equation Analysis in Biomedical Science and Engineering: Partial Differential Equation Applications with R*.



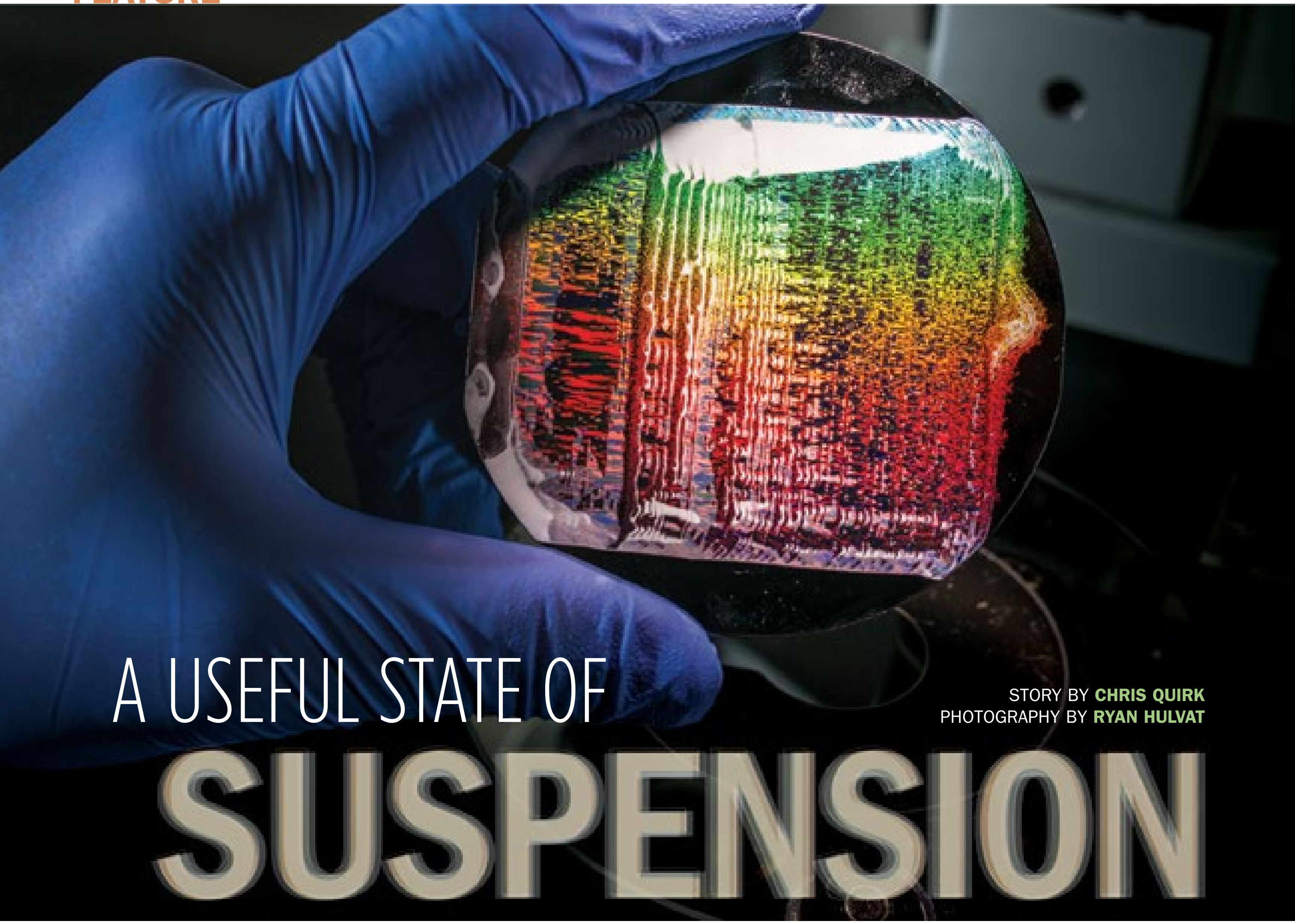
The three books represent the culmination of Schiesser's lifelong efforts to help students and peers use the computer to solve ordinary and partial differential equations. ODEs and PDEs are ideally suited, he says, for modeling the physiological phenomena he analyzes in *PDE Analysis in Biomedical Engineering*. These include the kinetics of antibody binding, the growth of tumors, the transport of oxygen in the retina, the dynamics of kidney dialysis, the healing of wounds and the distribution of encapsulated drugs.

"Our emphasis," says Schiesser, "is to put sets of differential equations on the computer, which can solve more complicated problems than a human being can."

As a teacher, Schiesser often used examples from biomedicine to show students how to solve differential equations on the computer. He created a library of routines for solving PDEs on the computer and made them available in Matlab and later in R. More than a thousand academic and industrial organizations have requested his software program in the past six years and used it to solve problems in medicine, geology, physics and other subjects.

In retirement, Schiesser has joined medical research teams at the University of Michigan and the University of Pennsylvania, where he works with ophthalmologists to mathematically model the diffusion of proteins in the retina.

"The diffusion of proteins in the retina is very important in macular degeneration, which is the leading cause of blindness in older people," he says. "The disease is not well understood, and the standard treatment is to give people injections of proteins in the eye. We've got to do better than that."



A USEFUL STATE OF SUSPENSION

STORY BY **CHRIS QUIRK**
PHOTOGRAPHY BY **RYAN HULVAT**

EXPLORING THE SEEMING CHAOS OF PARTICLE BEHAVIOR, RESEARCHERS DISCOVER A STARTLING DEGREE OF SELF-ORGANIZATION AND A WIDE ARRAY OF APPLICATIONS.

"This is as much art as it is science," says James Gilchrist, the Class of 1961 Associate Professor of Chemical Engineering. To the uninitiated, it might appear no small part magic as well.

Gilchrist focuses on a process—placing infinitesimally thin films of material onto substrates—that is deceptively simple but loaded with complexity and possibility.

Using a combination of high-end instruments and improvisational tools, he and his students explore the chaotic intricacies of particle behaviors, and a host of potential applications that these behaviors make possible. In the Laboratory for Particle Mixing and Self-Organization, Gilchrist works with a team of Ph.D. candidates and a senior polymers researcher. Since the field is wide open, the work demands creativity as well as discipline.

"There is much that we don't know yet about the structure and dynamics of the systems of suspensions and granular flow," Gilchrist says. "We can visualize a lot, but we can't visualize everything, so we have to imagine what's going on behind the scenes and what physics are impacting the interactions. That's where the creativity comes in.

"On the other hand, if we aren't disciplined in our experiments, our results won't let us see these physics in action."

The films that Gilchrist's group creates typically begin as fluid suspensions of minute particles that are often chosen for unique qualities that will yield a specific product or data. The suspensions are deposited microscopically or applied via a secondary carrier fluid. A considerable number of outcomes is made possible by manipulating the materials and the process, and the products emanating from the lab are highly sought after.

The variables in play in the manufacturing process are myriad. The ambient temperature, evaporation rate, surface tension and viscosity of the suspension fluid impact the final particle structure in the films. In addition, the speed and angle of the application plate, the qualities of the substrate, and the particle size can all be finely tuned. The goal of these manipulations is to reveal the essential characteristics of the process and the dynamics of complex interactions of suspensions.

What makes much of the group's work not just viable but valuable is a remarkable self-organization that frequently occurs, or is made to occur, as particles are applied during film deposition. Thanks to microscopic imaging, the researchers can watch a wedge scrape a fluid suspension loaded with particles across a flat surface. The layer of film that is left behind is a single particle thick. The suspended particles sort themselves into perfect arrays. Sometimes, when the array is inconsistent, the particles even correct and snap into place on the grid after a momentary delay once the wedge has moved past.

The seemingly magnetic—and fortuitous—phenomenon has been dubbed the "Cheerios effect." Just as bits of breakfast cereal floating in a bowl of milk will cling together, particles in a suspension can attract each other. The behavior is a combination of two factors. As particles are trapped in the film, they form dimples in the fluid's surface and drag neighboring particles toward them. In addition, because of the difference in pressure between fluid and air, the fluid surface can act like a membrane. This membrane resists objects that are pressed into it, causing further pressures that buffet suspended particles as a delicate equilibrium is formed where air and the denser fluid meet.

Particle structures in thin films are often hexagonal in form, though sometimes square (called cubic packing), the latter being less common but having useful properties. "If someone needs that, we can dial it in by changing the experimental conditions," Gilchrist says.

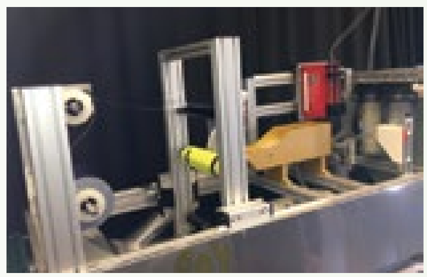
The spot (above) reflects the optimal ordering of light diffracted by a laser shining through a coating. At left, a rainbow of colors is generated by silica particles coating a silicon wafer.

CAPTURING LIGHT FROM LEDS...

One application for the particle structures that Gilchrist's group creates is the light-emitting diode, or LED, which is gaining popularity as a domestic lighting choice because of its superior energy efficiency. Gilchrist was approached by Nelson Tansu, associate professor of electrical and computer engineering, who produces high-end LEDs and wanted to make them brighter. The two researchers hypothesized that a particulate coating on the surface of an LED could improve light extraction within the LED—if well-chosen particles behaved like miniature lenses.

"The inside of an LED is a high-index refraction material, while air is low-index refraction," says Gilchrist. "Our first idea was to just use a rough surface to refract light, and extract it from the LED that way. We created a film—basically a microlens array—where the particles were the same gauge as the wavelengths of the light being emitted, which is where the efficiency comes in."

The researchers aimed for a 5- to 10-percent increase in the amount of light emitted from the LED. In their first trial, the LEDs produced twice the amount of light.



Muangnapoh, Perera, Joy and Joshi use a blade (right) and an Automated Langmuir-Blodgett (below) to deposit microscopically fine layers of particles.

Gilchrist now leads a group that is attempting to perfect the film. "The challenges are to make it more uniform and more efficient and to scale it up," he says. The group, which includes Mark Snyder, assistant professor of chemical engineering, has received a $1.1 million grant from NSF.

Eric Daniels, a research scientist, is working with Gilchrist on the NSF project, among others. He anchored the lab during Gilchrist's recent sabbatical at the California Institute of Technology, and his prior experience at Lehigh's Emulsion Polymers Institute has proved helpful, especially as EPI has been a major resource for many of the projects at the lab.

"We frequently use parts synthesized by EPI," says Gilchrist. "They are a crucial partner. The particles we use have to be uniform and manufactured to a critical tolerance. We could not do these projects without them."

"WE HAVE TO OPTIMIZE THIS THROUGH THE RIGHT **PARTICLE SIZE** AND **PORE SIZE**. IT'S VERY FULFILLING." —Alex Weldon

One of Daniels' main tasks has been preparing a recently acquired piece of hardware, an Automated Langmuir-Blodgett, for operation. Though it looks no more sophisticated than a stainless steel printing press, it has the potential to deposit a microscopically fine layer of particles using a wet-on-wet technique at high speed. With a mechanism that resembles a conveyer belt, the machine lays a suspension evenly on a fluid-laden substrate passing beneath it.

…AND PATHOGENS FROM THE BLOODSTREAM

The potential applications for thin films are so rich that, rather than having to seek collaborators, opportunities seem to come looking for Gilchrist and his crew. Alexander Weldon, who will complete his Ph.D. in May, is preparing a microfilm for use on a new device being developed by Xuanhong Cheng, assistant professor of materials science and engineering and bioengineering, to enable the capture of blood-borne pathogens.

"We'll put down layers of particles in their device, and functionalize them using antibodies or something that would bind to, say, a cancer cell," says Weldon. "The particles will grab pathogens and trigger an irreversible reaction. It could be used as a diagnostic or detection tool. We have to discover how to optimize this through the right particle size and pore size. It's a very fulfilling collaboration." Weldon was lead author on a paper in *Applied Materials and Interfaces* that showed how to employ two particles of different sizes to create a film with pores that could be fine-tuned to filter such targeted pathogens out of blood or other suspensions.

The potential for the work coming out of Gilchrist's lab is versatile. And while more efficient LEDs and solar cells, pathogen detectors, better batteries and higher-resolution HD displays are just some of the beguiling applications of thin films, that's not how Gilchrist interprets his mandate. "We're here to do fundamental science," he says. "We are not going to be the people that coat things—we want to enable others to coat things better."

One fundamental problem that the group is exploring is the radical change in viscosity and particle behavior that a suspension can undergo when it is sheared. Rubbing a suspension between thumb and forefinger is an example of shearing; as the internal structure changes, it changes the viscosity.

LEARNING FROM ANOMALIES…

Tharanga Perera, a Ph.D. candidate, is attempting to reconcile empirical results with theoretical calculations on the shearing of suspensions. The calculations have been unresolved for almost 20 years. One challenge is to locate and track individual particles in a suspension. To test and verify the existing numerical calculations, Perera uses sophisticated confocal microscopy that can capture a 3D nanoscale image at high speed. This allows him to experimentally determine particle location and check the results against computer simulations. To generate more robust data, he makes changes in the experiments that cannot be executed on the computer.

Along with the successes come equally prized anomalies, which frequently spark innovation. “We can do an experiment where 90 percent of things go the way we anticipate,” says Gilchrist, “but a lot of our most interesting work ends up being driven by the 10 percent we aren’t expecting.”

While working with inorganic, magnesium oxide films, Midhun Joy, a Ph.D. candidate, came across a way of more easily creating cubic-packed structures in the films by changing the substrate properties. His motivation was to avoid the cracks that had been occurring in films placed on less flexible glass carriers. While he was examining a sample done with the polymer substrate, Joy noticed the cubic structure of the particles—a happy, but unanticipated, result.

“We don’t understand exactly why this is happening, so we’re studying the fundamentals of how it occurs,” said Gilchrist. Other engineers have expressed strong interest in the possibilities for this work.

In another project, Tanyakorn Muangnapoh, a Ph.D. candidate, came to Gilchrist with a problem: How could the group deal with unavoidable vibrations that affected the manufacturing process as film was being deposited? The group came up with the novel idea of deliberately adding vibrations into the deposition process to determine if they might actually be beneficial.

“It was as if we decided to shake a gumball machine to see if we could get more efficient packing,” Gilchrist says. Muangnapoh tried different parameters and reported positive results.

“He told me the good news, that the vibrations produced these nice monolayer coatings,” says Gilchrist. “The ‘bad’ news was that even when he altered the parameters, he still got the monolayer coatings. We weren’t expecting that.”

Muangnapoh, with Weldon and Gilchrist as coauthors, recently described his results in a paper published in *Applied Physics Letters*. “We still don’t totally know what’s going on,” says Gilchrist. “We understand the heuristics of it; now we need to keep working to find out fundamentally what’s happening.”

…AND FROM FAILURES

Failure is sometimes more than an option; it is actively pursued and analyzed.

“We’ve spent a lot of time studying how things go wrong as opposed to right,” Gilchrist says. For instance, if something goes wrong during the particle deposition process—if particles of different sizes fall awry, if an impurity is introduced or if a heated substrate causes the film to buckle—the defect can snowball and become irreversible, resulting in stripes or streaking in the film.

Kedar Joshi, a Ph.D. candidate, is seeking to find out if adding surfactants to a suspension will reduce the surface tensions to avoid these instabilities. Gilchrist and his students have created hundreds of failed samples to better understand the minute choreography that takes place in these nanoparticle pileups.

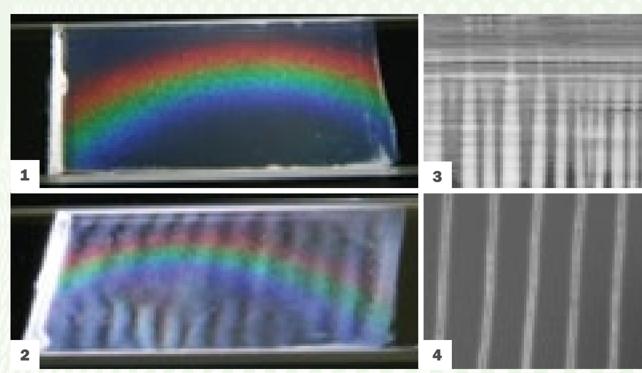


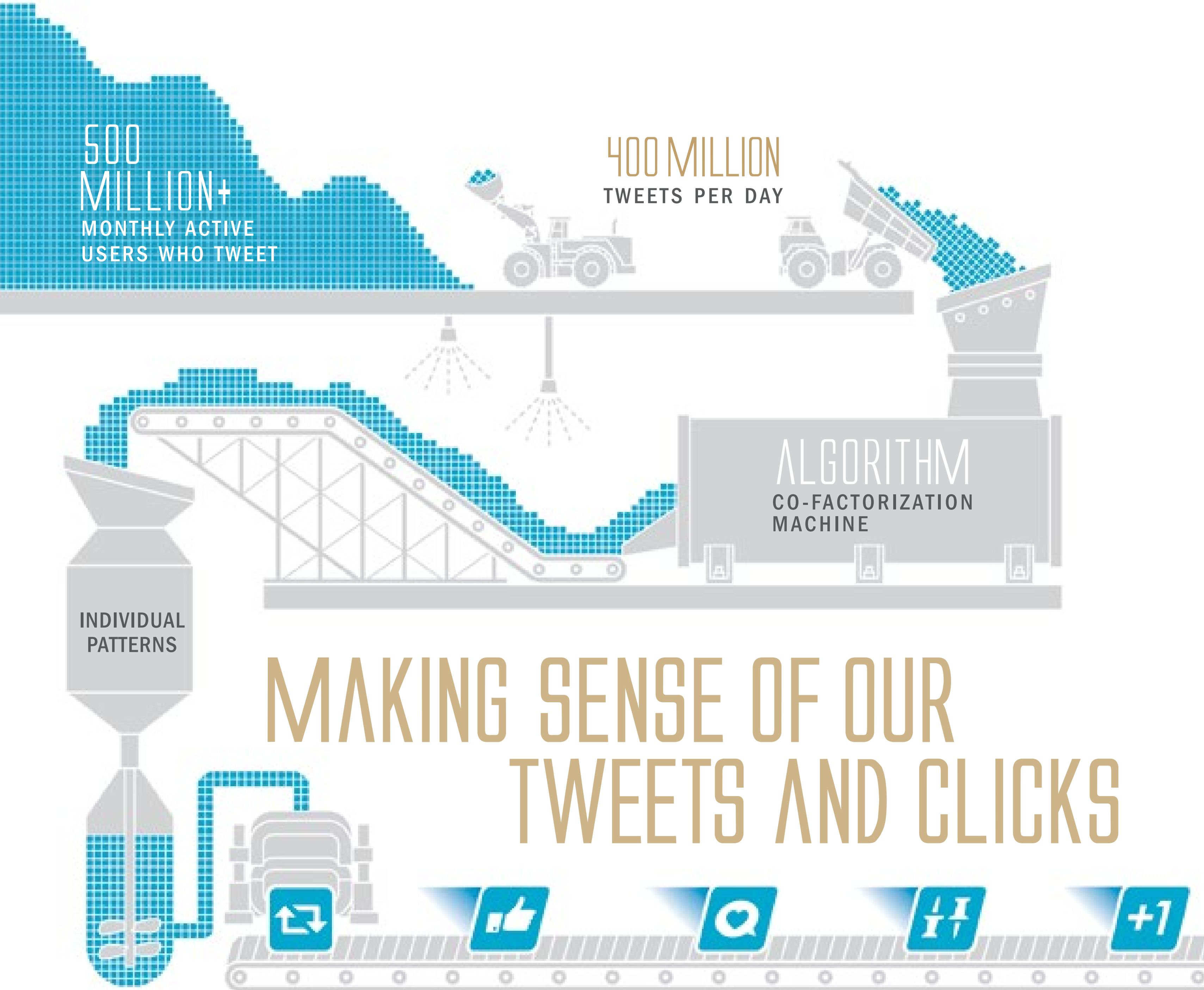
*Image **1** shows ideal coating. Image **2**, **3** and **4** show the stripes, streaks and cracks that form when the process goes amiss.*

“You can’t predict this stuff,” says Gilchrist. “The LED improvements, in part, came about because a student was dissatisfied with the project he was working on. We’ve had some major discoveries by dissatisfied students.

“My students are independent. I want them to tell me I’m wrong,” Gilchrist says. “Often, when I have students facing a challenge, I tell them to try a number of things. They often say, ‘I already did.’

“I love that. My attitude is that if you receive your Ph.D., you should be one of the world’s leading experts on your topic. That says all you need to know about the quality of our chemical engineering program at Lehigh.”

STORY BY **ROBERT W. FISHER '79** ILLUSTRATION BY **JAMES PROVOST**



MAKING SENSE OF OUR TWEETS AND CLICKS

COMPUTER SCIENTISTS TRAIN ALGORITHMS TO KEEP PACE WITH THE DATA EXPLOSION.

With a torrent of new content unleashed on the Internet every hour, how do you find the news articles, status updates and videos you want to view? How do websites like Yahoo and Facebook feed you enough interesting content to make you want to click on the ads?

"We process terabytes of data every hour," says Liangjie Hong '13 Ph.D., a scientist at Yahoo! Labs. "You cannot consume it all."

"If you're really engaged, you have too many people to keep up with," agrees Brian Davison, associate professor of computer science and engineering and head of Lehigh's Web Understanding, Modeling and Evaluation (WUME) laboratory. Davison himself follows hundreds of people on sites like Facebook, where he is spending the 2013-14 academic year on sabbatical in the data science group.

Davison and Hong have collaborated on an innovative project that attempts to discern users' behavior from a small sample of online activity and then predict the types of content users would like to see.

"If we can better understand what you are interested in," says Davison, "we can decide what to filter, rank higher or flag for your attention."

The two researchers analyzed a spurt of Twitter activity, including millions of tweets posted by thousands of individual users. Then they trained an algorithm to predict with high accuracy how often the recipients of tweets would "retweet," or rebroadcast, the messages to their own followers. They received a best poster award at the 2011 World Wide Web Conference and then decided they could obtain more relevant information by modeling how users respond to new content.

"If we could record a user's activities for 24 hours," says Hong, "we would know exactly what they are looking for."

Even power users, however, leave only a handful of clicks to analyze. So Davison and Hong turned their focus to the likelihood that an individual user will pass along a specific message. They developed co-factorization machines, which use a mathematical analysis method to examine how users interact with tweets. Do they reply? Do they retweet? Which tweets do they mark as favorites? The researchers' technique also determines users' possible interests based, among other things, on the frequency with which specific terms appear in their feeds.

"People have patterns for retweeting," Hong says. Some never retweet. Others primarily pass along tweets from prominent users. Others focus on topics they're passionate about, such as a sports team or an entertainer.

Finding patterns in terabytes of data is a huge challenge, Hong says, but mining data flows for individual patterns can simplify the effort. A particular user is interested in only a tiny fraction of the topics covered on the Internet, he says. This reduces the amount of data that researchers have to process and enables them to make narrow predictions about users' behavior.

The algorithms developed by Davison and Hong improve their predictions through a technique known as machine learning. Rather than explicitly programming rules for how users will respond to tweets, the algorithms "learn" from the results of past interactions to build and refine rules for individual users. This research was a finalist for the best paper award at ACM's (the Association for Computing Machinery) Sixth International Conference on Web Search and Data Mining (WSDM) in Rome in 2013.

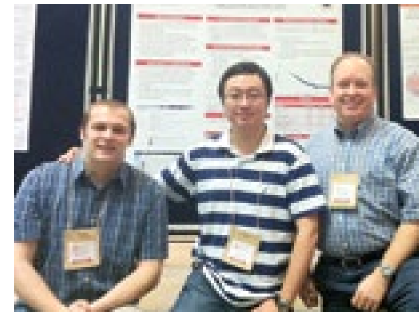
The quest to model an individual's interests is as old as the card catalog, Davison says, "and it's not going away."

Davison predicts algorithms will soon customize a social media user's experience, ensuring they see every post by a family member while offering insights on favorite topics from sources the user has yet to hear of.

At Yahoo! Labs, says Hong, scientists run real-time experiments every day, varying the arrangement and selection of millions of news articles, search results, Tumblr posts and Flickr photos. A click you made months ago can provide clues that help match today's content with your interests.

"From a business point of view," he says, "if we can provide personalized content, we can make more money from ads."

Davison recognizes that increasing customization can exacerbate



Liangjie Hong (with Ph.D. candidate Ovidiu Dan, left, and Davison, right) says the WUME lab's Hadoop parallel processing environment, a rarity for universities, helped prepare him for his career with Yahoo! Labs.

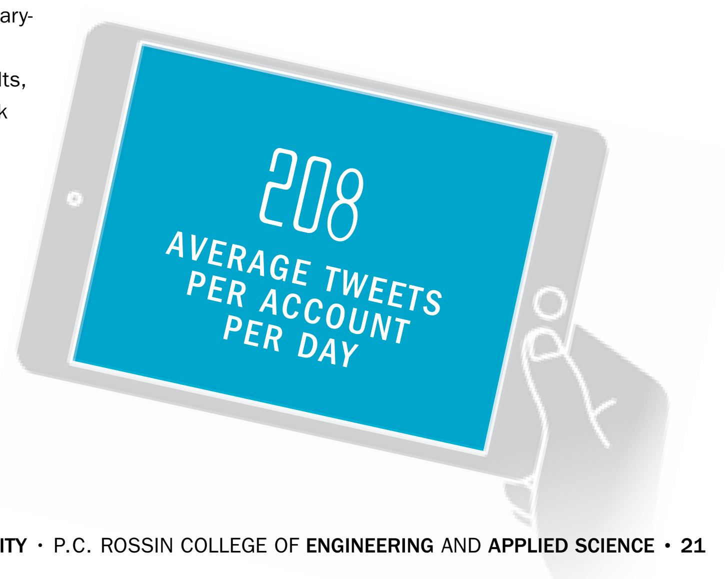
the "filter bubble" effect, in which people get information from an echo chamber of like-minded sources. With funding from a Lehigh Faculty Innovation Grant, he is studying how people perceive bias in online news.

"News outlets can tell the same story from very different perspectives," he says. "We want to see if people can recognize different types of bias," such as a political or gender orientation, a lack of objectivity or a negative approach.

Eventually, he plans to tackle the subtle problem of bias by omission, an example of which is when a news outlet never criticizes its corporate parent. Someday you may be able to set a "bot" on your system that will seek out articles that cover your favorite topics with a different slant, he says.

In the meantime, web companies will continue to look for patterns in the data you view and post online, while relying on human nature to fill gaps in the technology.

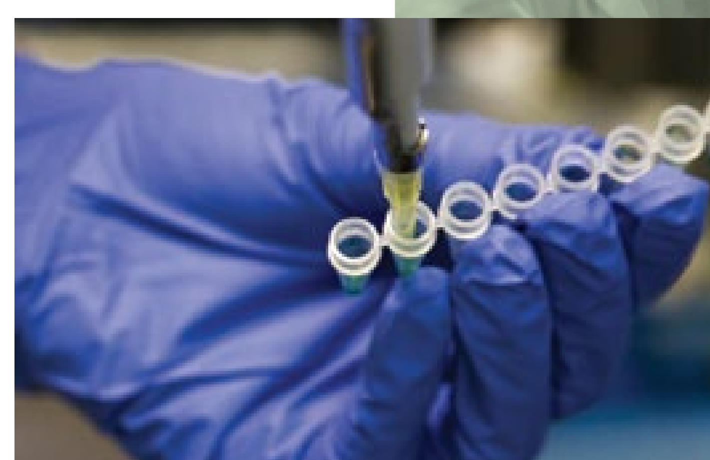
"How users respond to information and how they decide whether or not to pass it along," says Hong, "is usually based on a mixture of personalization and popularity. We need to offer you the information that is most relevant to you."



FEATURE

ENGINEERS AND BIOLOGISTS FIND COMMON GROUND IN A
DYNAMIC SUMMER RESEARCH PROGRAM

CREATIVITY IN THE GAP



NEAR THE CENTER OF NEAL SIMON'S DESK sits a baseball-sized marble sphere, a gift from a friend in graduate school.

"He said, 'Whatever way you look at it, you can't see the other side,'" says Simon, professor of behavioral neuroscience in the College of Arts and Sciences (CAS). "'But you need to understand how people on the other side are thinking.'"

Today, life scientists need to consider the perspective and contributions of people on the other side of the ball, who include engineers, computer scientists, mathematicians and even business people.

Hard-and-fast boundaries between disciplines, says Simon, no longer exist. "What we try to do is bring an appropriately diverse skill set to bear on modern biological problems."

To help students see their fields in the larger context of modern life science, Simon and Vassie C. Ware, professor of molecular biology in the CAS, won funding in 2006 from the Howard Hughes Medical Institute to create the Biosystems Dynamics Summer Institute (BDSI). The research program teams undergraduates with peers, graduate students and faculty from biology, engineering and other fields. When a second round of funding, which was received from HHMI in 2010, ends this year, BDSI will become a Lehigh-funded program.

The key to BDSI, says Ware, is that "we invite undergraduates to be involved with a large bioscience problem that is of interest to faculty from different disciplines. These faculty teams have a vested interest in the solution and in sharing the work with undergraduates and graduate students."

"I have undergraduates in my lab all year," says Yevgeny Berdichevsky, assistant professor of electrical and computer engineering. "In the summer, they see how I work with graduate students and get a bigger sense of the project. They are full participants in the research."




Each year the BDSI program accepts 16 to 20 students, from Lehigh and other schools, out of nearly 100 who apply. For 10 weeks the students conduct research in four to six teams. Guided by faculty and graduate students, they learn to work independently and produce publishable papers, posters and presentations.

One goal of BDSI is to break down cultural barriers between biologists and engineers.

"Biology is a hypothesis-driven field," says Simon. "Engineering is about the application of knowledge to address specific issues."

"Engineers tend to be technology-centric," says Berdichevsky, who co-led a team using advanced microscopy to study whether post-traumatic epilepsy kills neurons. "Medically oriented scientists are more interested in how they can cure a specific disease, but they are not necessarily aware of the technological possibilities."

Nicole Pirozzi, a senior bioengineering major who worked on Berdichevsky's team, says biological literature can frustrate her. "They'll say, 'This was observed.' But when? How much? Is it measured over time so you can see improvement?"

biology and psychology, worked in 2012 with Yaling Liu, associate professor of mechanical engineering and mechanics, and Linda Lowe-Krentz, professor of cell biology (CAS). Their goal is to develop a method of testing cancer drugs on a chip etched with channels that are coated with human endothelial cells.

"We weren't just culturing cells, we were actually building microdevices to test fluid shear forces in the bloodstream," Rowan says. "To say I just do biological research is short-sighted, because I know I will have to work with people from other disciplines to make real progress."

Bryan Berger, assistant professor of chemical engineering, and M. Kathryn Iovine, associate professor of evolutionary biology (CAS), led a team that studied how protein receptors help zebrafish regenerate missing fins. "We are looking at physiology from the organism level down to the molecular level, where bioengineering and microbiology students offer a lot," says Berger.

The team's students came from backgrounds as varied as mathematics and the Integrated Business and Engineering (IBE) Honors Program.

Sam Flores, a junior majoring in molecular biology, learned about organizing data and using computers from Durlav Mudbhari, an IBE junior who kept a protein purification

"If you can understand what others have to offer, it grows your base of knowledge so much more than just studying in your own field."

—Nicole Pirozzi '14

Now Pirozzi sees how her experience can bridge disciplines. "As a bioengineer, every project I work on will be interdisciplinary. It's intuitive that people like me would be in the gap, creating innovation not just by understanding a (biological) process but by knowing how to improve it.

"I learned that it's OK not to know everything about everything. If you can understand what others have to offer, it grows your base of knowledge so much more than just studying in your own field."

Aislinn Rowan, a senior majoring in

apparatus running in optimal condition.

"I didn't have much biology experience," Mudbhari says. "It was interesting to see how my engineering background could merge with biological science. BDSI taught me how to do research and be independent."

Alyssa Driscoll, a senior bioengineering major, says BDSI was much more demanding than other research experiences.

"It's not like a course lab where you know what answer you're supposed to get. It was very much, 'Go, do your thing.' We learned fast. It was so self-motivating."

By degrading a biofilm with a polysaccharide lyase, Bryan Berger (with Ph.D. candidate Zhou Yang at right) has been able to break the cycle of drug resistance.

This biomedical researcher carries his own tune

Bryan Berger customizes solutions to the growing problem of drug-resistant bacteria.

It's not the way the tune usually goes. Growing up, Bryan Berger avidly pursued both music and science. He began his undergraduate studies at the University of Illinois Urbana-Champaign in music performance, but switched to engineering after his first year.

"I played piano and French horn," says Berger, assistant professor of chemical engineering, "but on my father's side of the family they are all engineers, so it was kind of natural."

After switching majors, Berger joined the less demanding, non-performing orchestra at the school. "They called it, aptly as it turns out, the engineering orchestra."

Two years ago, he began collaborating with doctors at Lehigh Valley Health Network (LVHN) to combat *stentrophomonas maltophilia*, an emerging, drug-resistant bacteria that was causing a high rate of lung infections at the hospital.

As a chemical engineer, Berger brought quantitative and modeling skills and a problem-solving mentality to the table. After identifying the bacterial culprit by analyzing proteins in patients, Berger devised a novel way to isolate and expose it.

"Drug resistance is a huge problem," says Berger, "and there's no one-size-fits-all solution. If you try to eradicate a bacteria by applying selective pressure to a protein that it secretes, the bacteria will adapt and generate a different protein. It's not a very good long-term solution."

Instead, Berger targeted the biofilm that the bacteria produces for protection. These exopolysaccharides are gel-like sugar compounds that Berger likens to the illustrations of tartar you might see in a toothpaste commercial. They provide a shell that helps the bacteria avoid detection by a host and penetration by antibacterial drugs.

"If we inhibit the film production process early, it leaves the pathogen exposed, and the immune system has a better shot at fighting the bacteria," he says.

Berger uses a polysaccharide lyase, Smlt1473, to degrade the biofilm. It has the added benefit of breaking the cycle of drug-resistance. "If bacteria is under stress from an antibacterial," he says, "there's a strong incentive to react to remain viable. It's less likely the bacteria will evolve with this approach, because attacking the film doesn't trigger the same stress response."

The collaboration with LVHN and other partners generates educational fringe benefits, Berger says.

"It's not always obvious how deeply science, physics, chemistry and the like connect to society. With projects like this, students learn firsthand the impact of their work."

The polysaccharide lyase also degrades many kinds of polymers, says Berger. "It's funny, a lot of my mom's side of the family worked in the Chicago stockyards, and we've now been approached by Sterilex, which serves the meatpacking industry, to see if it might be useful to them."

Another of Berger's projects involves quantum dots—semiconductor nanoparticles that can be pricey to produce—and serendipity.

"This *stentrophomonas maltophilia* that causes lung infections is nasty, and it can also mow right through silver, which is scary as silver is often used as an antibacterial. On the other hand, it's a remarkable cell that creates well-defined nanoparticles that are hard to make in the lab. You can throw all kinds of metals at it and it will spit them out embedded in these particles."

Berger has devised a way of producing quantum dots using an engineered form of the bacteria that he's patented. It employs the bacteria's own threat response to the metal introduced, cadmium in this case, which the bacteria removes by precipitating it out in metal-loaded quantum dots.

"It's very scalable," Berger says, "and you can make these dots at a tiny fraction of the usual cost of producing them. My original thought for them was solar cells, but I bumped into Steve McIntosh [associate professor of chemical engineering], and he suggested we take the quantum dots and use a photocatalytic process to make liquid fuel from water and sunlight—basically artificial photosynthesis."

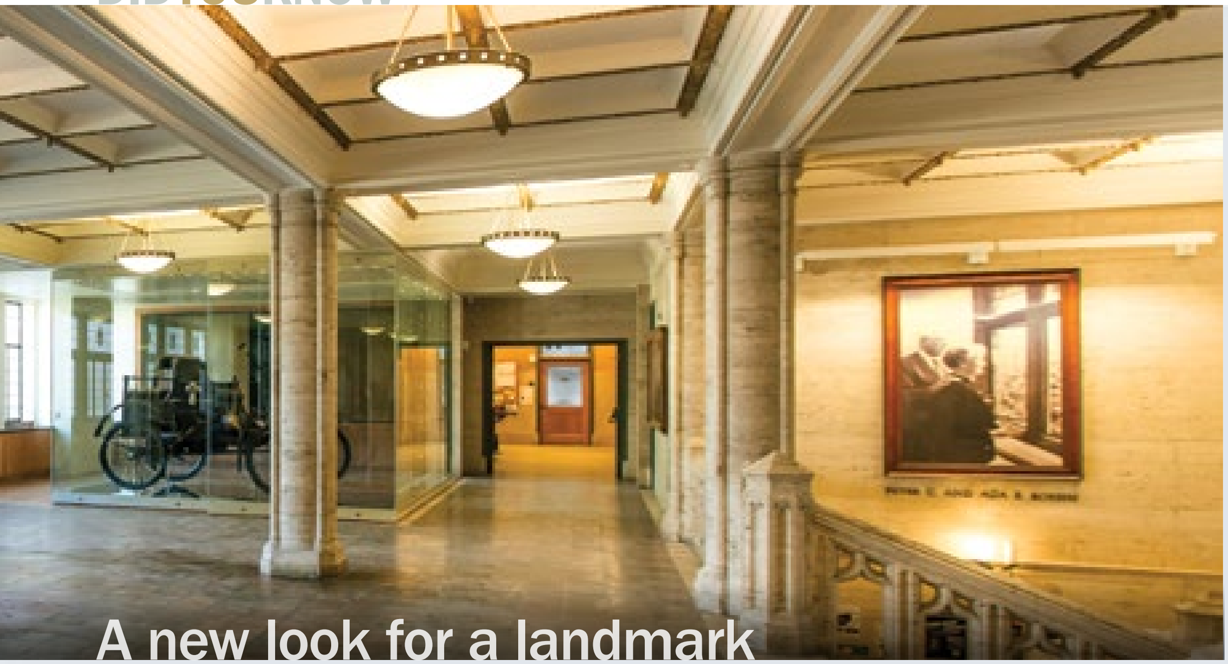
The resulting methanol is clean to produce, it burns cleanly and it should be competitively priced. Berger and McIntosh received a major grant from NSF to expand their project.

"You don't know where it will go when you start, and you have to be tenacious, but if I had begun aiming for these things, I never would have reached them. It's only through the process of research and

developing ideas that you find solutions."

As for music, Berger is keeping up his chops, though he doesn't have as much time to woodshed as he might like.

"I play with a community group and with the orchestra in Doylestown," he says, "but these days my plate is pretty full."



A new look for a landmark

THE MAIN LOBBY OF LEHIGH'S HISTORIC PACKARD LABORATORY is being renovated to serve as a destination point for students and visitors. New features include a media wall, a collaborative learning space and an environmentally controlled glass case for the 1899 Model A-1, the first car ever built by the Packard Motor Car Co.

Other features from the venerable building and its history:

- Packard Lab was constructed in 1930 of steel and native Pennsylvania sandstone and trimmed with Indiana limestone. Its architects, Lehigh alumni Theodore Visscher 1899 and James Burley 1894, also designed Lehigh's Alumni Memorial Building, Chandler-Ullmann Laboratory and Grace Hall.

- The building originally contained a 223-by-63-foot, three-story-tall lab space, with a floor that could withstand 400 pounds per square foot of pressure and with spacious observation balconies that could accommodate smaller projects and light machinery. This space was replaced in 1976 with labs and offices.

- Statues of Michael Faraday and James Watt preside over the main entrance, symbolizing the building's original dedication to electrical and mechanical engineering.

- Until recently, Packard's classrooms were locked by professors immediately after the bell sounded to begin class. For several generations, tardy students signaled sympathetic peers with a "secret knock" to open the door and allow them entry at an opportune moment.

- Today, Packard is home to the P.C. Rossin College of Engineering and Applied Science and its departments of electrical and computer engineering, mechanical engineering and mechanics, and computer science and engineering.

JAMES WARD PACKARD

(1863-1928) was making incandescent lamps in Ohio in the early 1890s when he saw an opportunity to improve the automobiles that were just beginning to appear on America's roadways.

Packard and his brother, William, joined forces with an investor in 1893 to found what became the Packard Motor Car Co. The first Packard car, called the Model A-1, was designed and assembled by James Packard, and it rolled out in 1899.

The A-1's top speed is about 35 miles per hour. Its wheels measure 34 inches in diameter, its pneumatic tires 3 inches in width. The seamless steel frame is made flexible by ball joints. Double elliptical springs support the rear, with a reversed elliptical spring in front. The roller gear and chain drive are of nickel steel. A foot pedal controls speed.

The A-1's ignition and engine were considered superior to those of any other car then on the market.

Packard, who had earned a degree in mechanical engineering from Lehigh in 1884, was awarded more than 40 patents in his lifetime. Six were for parts used in the A-1, among them the H-pattern gear slot.

In 1927, Packard donated $1 million to Lehigh to build "the finest laboratory." The first A-1 ever built, known affectionately as "Old Number One," arrived just in time for the dedication of Packard Laboratory in 1930.

To learn more about the achievements of Lehigh engineers, visit

lehigh.edu/engineering

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A THOUSAND TALES OF INDIVIDUAL RELATIONSHIPS

Peter Linz, a physician with the global charity Mercy Ships, says the humanitarian work he has done in African countries can be draining given the sheer numbers of people in need. The rewards—restoring a person's sight or removing a facial tumor—are achieved by solving one challenge at a time.

See page 8