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EQuad News

Summer 2018
Volume 30, Number 1

SECURITY PRIVACY HUMANITY

PRINCETON
School of Engineering
and Applied Science

DEAN'S NOTE

Making computers work for people

When Brad Smith '81, the president of Microsoft, spoke on campus this spring, he posed provocative and important questions: "Will we ensure that machines remain accountable to people? Will we ensure that the people who design these machines remain accountable to other people?" (See story, page 9).

Brad was speaking in the context of artificial intelligence (AI) and its many promises and potential pitfalls, but his questions apply equally to most computing and communications technologies. How do we ensure that the devices, networks, and algorithms we create truly serve humanity? How do we build in, at the very core, safeguards of privacy, security, and fairness, so that even users with no technical background have assurances of safety and control?


Photo by David Kelly Crow

These are giant questions, far broader than any single institution can answer. But many Princeton faculty members and students are focused on these problems, and we feature a sampling in this magazine. Among many examples, Princeton's Center for Information Technology Policy recently teamed with the University Center for Human Values to create "Princeton Dialogues on AI and Ethics," a series of conferences and case studies to help guide practitioners and policymakers.

In 2014, Supreme Court Justice Sonya Sotomayor '76 gave a speech on campus that inspired Princeton to change its informal motto to "In the nation's service and the service of humanity." Her point of focusing on people rather than national (or corporate) constructs seems particularly relevant in addressing the sweeping impacts of technology. I believe we must bring together diverse strengths and expertise — from engineers to humanists, from many personal backgrounds — to ensure that technology serves people.

What do you see as the greatest opportunities and risks that emerging technologies bring to society? Please write us at eqn@princeton.edu or join us on social media.

Emily Carter
Dean
Gerhard R. Andlinger Professor in Energy and the Environment
Professor of Mechanical and Aerospace Engineering and Applied and Computational Mathematics

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Note on alumni class years
Following Princeton University convention, undergraduate alumni are indicated by an apostrophe and class year; graduate alumni, whether master's or doctoral, are indicated with a star and class year.

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In the Nation's Service and the Service of Humanity

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Photo by Sameer A. Khan/Fotobuddy

DAY OF DEMOS MESMERIZES ELEMENTARY SCHOOLERS VISITING ENGINEERING SCHOOL

Mechanical and aerospace engineering graduate student Ting-Hsuan Chen *18 guides students in using the department's immersive flight simulator.

About 15 elementary school students stood stock-still, their attention locked on engineering graduate student Renato Pagliara Vasquez as he struggled to make a robotic arm balance one thin stick on top of another.

"This is a really hard problem," fellow graduate student Anastasia Bizyaeva explained as Pagliara reset the computer that controlled the system and lifted the two sticks into a vertical position. The robotic arm snapped into action, balancing the sticks as a single column.

"Oooh," said the group, a subset of about 70 students from Harlem Prep Elementary School in New York City.

Like a robotic circus performer, the robot made tiny, rapid adjustments that kept the sticks vertical.

"Three … two … one," said Pagliara, turning off the control system and letting the sticks fall.

"Oh, that's cool!" yelled the students.

The April 19 presentation marked the sixth annual visit by Harlem Prep students to the Department of Mechanical and Aerospace Engineering at Princeton University. The event, organized by lab manager Tyler Van Buren and graduate student Dan Floryan, involved 21 student and staff volunteers who ran demonstrations and helped with organization and planning. It's fun, and also educational, Van Buren said. The students participate in demonstrations and activities linked to their classwork in school.

"Also, seeing young people get so excited about the things we work on every day helps reignite our excitement for research," he said.

Pagliara brought the point home after his demonstration. "This is how students at universities learn to build the systems and do the programming to make self-driving cars," he told the students.

Pointing to the robot, Pagliara encouraged the group to study and work hard.

"Come help us design and make better controllers," Pagliara said, "so we can make better self-driving cars and better robots."

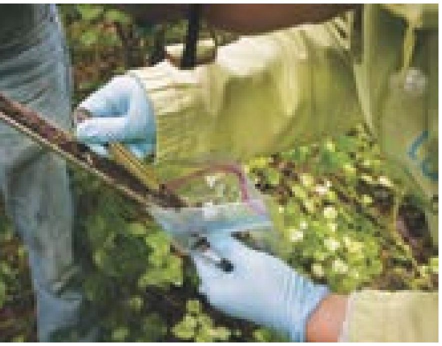
Just before wrapping up the visit with an ice cream treat, Harlem Prep students were eager to call out parts of the day they liked.

"I liked the robot!" said Bintu, 9, referring to Baxter, the robot used in the MAE department's teaching labs. "I'd like to make a little dog or something that can play." Her friend Keira, 9, also liked Baxter. "He dabbed!" she said, referring to Baxter's signature dance move.

"I liked the rocket science," said Sebastian, 9. "They build stuff for NASA! If I learn enough, maybe I can do it. I'd build a robot." **–Steven Schultz**

Photo by David Kelly Crow

Photo by Frank Wojciechowski



Right: Princeton professor Peter Jaffé and researcher Shan Huang have discovered a bacterium that offers a more efficient way to treat sewage and other pollutants.

Above: Researchers identified the bacterium in a New Jersey wetland.

SWAMP MICROBE HAS POLLUTION-MUNCHING POWER

Sewage treatment may be an unglamorous job, but bacteria are happy to do it. Sewage plants rely on bacteria to remove environmental toxins from waste so that the processed water can be safely discharged into oceans and rivers.

Now, a bacterium discovered by Princeton engineers in a New Jersey swamp may offer a more efficient method for treating toxins found in sewage, fertilizer runoff, and other forms of water pollution.

The bacterium, *Acidimicrobiaceae bacterium* A6, is capable of breaking down ammonium, a pollutant found in sewage and fertilizer runoff. Even more intriguing is that A6 can perform this chemical conversion in the absence of oxygen, an ability that could be useful for providing alternative methods to costly oxygen-dependent methods currently used in sewage treatment and other processes.

"A great deal of energy is used by machinery that mixes air into wastewater to provide oxygen for breaking down ammonium," said Peter Jaffé, the William L. Knapp '47 Professor of Civil Engineering and associate director for research at the Andlinger Center for Energy and the Environment. "A6 carries out this same reaction anaerobically and might present a more efficient method for treating ammonium and a way to treat other environmental pollutants found in oxygen-poor areas, such as underground aquifers."

Removing ammonium is important to prevent depletion of oxygen in streams and to prevent eutrophication, the growth of excessive algae and other plants triggered by nitrogen compounds from sewage and agricultural runoff.

An alternative chemical process for breaking down ammonium, known as Feammox, occurs in acidic, iron-rich, wetland environments and soils. It was not clear, however, what enabled the Feammox reaction.

Jaffé and his colleague Shan Huang, an associate research scholar at Princeton, had a hunch that the A6 bacterium might be at the root of the process when studying samples taken from the Assunpink wetland near Trenton, New Jersey. The researchers reported the result in April in the journal PLOS ONE.

"We've suspected that a bacterium was doing the heavy lifting," Jaffé says. "This study confirmed that A6 has this ability, making it the first species known to carry out the Feammox reaction."

The Princeton team is exploring how to build a reactor where A6 could be used to process ammonium at industrial scales.

"It could become a very important tool for addressing a range of environmental problems," Jaffé said. **–Chris Emery**

RESEARCHERS USE LIGHT TO TURN YEAST INTO BIOCHEMICAL FACTORIES

Princeton researchers have developed a method to use light to control the metabolism, or basic chemical process, of a cell. In experiments, they used the technique to increase genetically modified yeast's output of commercially valuable chemicals.

"This technique allows us to control the metabolism of cells in an unprecedented way," said co-lead researcher José Avalos, an assistant professor of chemical and biological engineering and Princeton's Andlinger Center for Energy and the Environment. "It opens the door to controlling metabolism with light."

The researchers used light to switch on genes that they had added to the yeast cells. These particular genes are sensitive to light, which can trigger or suppress their activity. In one case, turning on and off a blue light caused the special yeast to alternate between producing ethanol, a product of normal fermentation, and isobutanol, a chemical that kills yeast at sufficient concentration.

Although natural yeast fermentation produces isobutanol, it does so in miniscule amounts. Instead, yeast make high volumes of ethanol and carbon dioxide. The researchers predicted they could use a combination of genetic engineering and light to fine tune isobutanol production. Using their light-switch technique, the researchers set out to keep the yeast alive while maximizing isobutanol production.

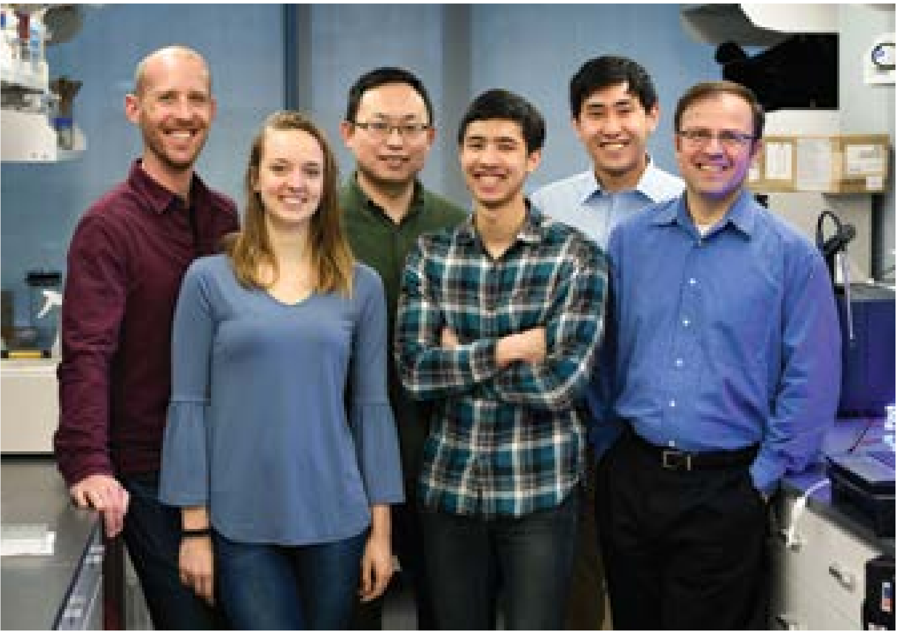
The researchers allowed the cells to grow by giving them bursts of blue light every few hours. In between they turned the light off to shift their metabolism from powering growth to producing isobutanol. Before the cells completely arrested, the researchers dispersed more bursts of light.

"Just enough light to keep the cells alive… but still crank out a whole lot of product that you want, which they produce only in the dark," said Jared Toettcher, an assistant professor of molecular biology and co-lead researcher.

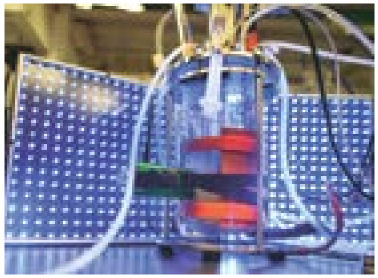
The researchers published their results in the journal Nature in March and now are working to improve their results. They have recently tested different colors of light to activate various proteins and cut the time needed for yeast to produce desired chemicals. But he said they would ultimately like to expand the scope of their work.

"Metabolic engineering transcends industrial microbiology," Avalos said. "It also allows us to study the metabolism of cells for health-related problems. You can control metabolism in any context, for industrial biology or to address medical questions."

–Lonnie Shekhtman



Photos by Sameer A. Khan/Fotobuddy



Above:
Researchers used blue light to control genetically modified yeast and increase its production of commercially valuable chemicals.

Below: Researchers involved in the project included Assistant Professor Jared E. Toettcher; Helen Park '18; Yanfei Zhang, postdoctoral research associate; Makoto Lalwani and Evan Zhang, graduate students in chemical and biological engineering; and Assistant Professor José Avalos.

NEW MATERIAL COULD LOWER COST OF CARBON CAPTURE

As long as climate change has been in the news, carbon capture and storage has been part of the discussion.

But so far, it largely hasn't been put into practice at coal-fired power plants and cement manufacturing facilities — two of the major emitters of carbon dioxide — because of carbon capture's expense.

Now, a team of Princeton Engineering researchers has developed a method based on theoretical calculations they believe could drive down the cost of carbon capture. Rather than the common method of absorbing the carbon dioxide in a liquid chemical solution like amine, the researchers, led by Claire White, propose using a sheet of mineral material to which the CO_2 sticks.

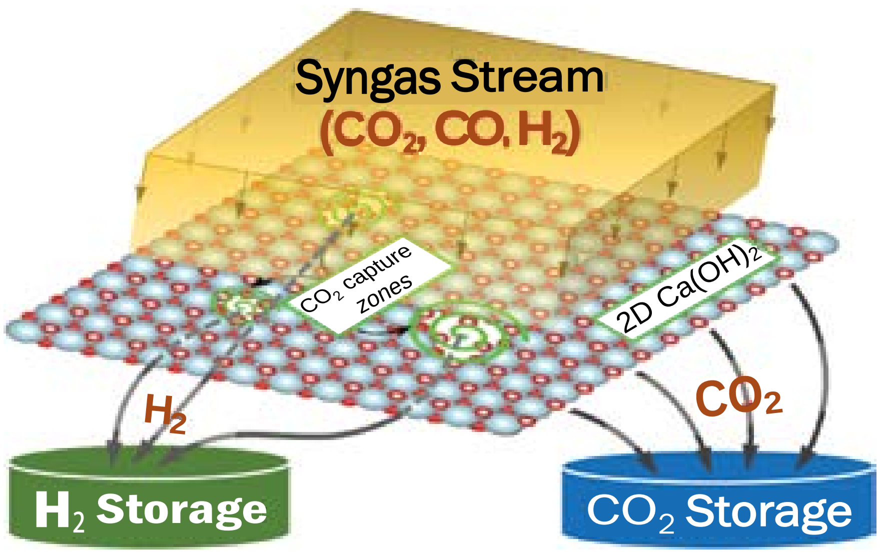


Illustration courtesy of the researchers

Researchers have calculated that it is possible to use extremely thin sheets of the material portlandite to efficiently capture carbon dioxide at industrial facilities including power plants and cement factories, to prevent the greenhouse gas from entering the atmosphere.

That, she said, is likely to make it easier and less expensive for the carbon dioxide to then be pulled off the material for storage. The material itself is reused for further carbon capture.

White is an assistant professor of civil and environmental engineering and the Andlinger Center for Energy and the Environment at Princeton. The lead author on the paper, published earlier this year in the journal Nano Letters, is Ongun Ozcelik, a postdoctoral researcher. The other author is graduate student Kai Gong.

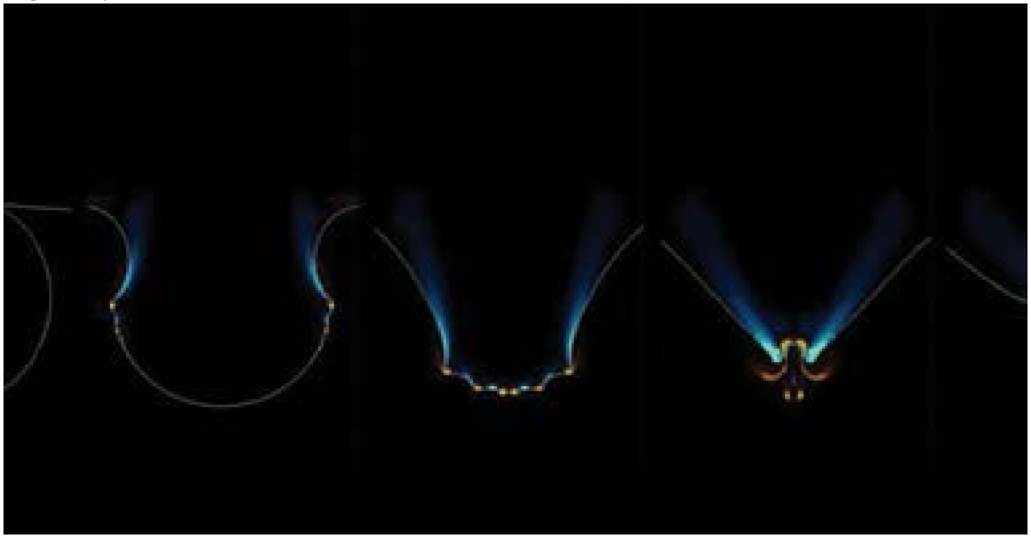
The material they use for the carbon dioxide capture is portlandite, which is made by heating limestone and then soaking it in water. The researchers "peel" the material into atomically thin layers to increase the surface area and therefore the material's ability to capture CO_2. The team has calculated that further tweaks to the material could allow for even more carbon dioxide to be captured, Ozcelik said.

"What this theoretical study shows is that you can design new materials that hopefully don't require so much energy for rejuvenation, and therefore retain most of the energy efficiency of the entire plant when you do carbon dioxide capture," White said.

While they have not taken steps to commercialize this research, a promising feature of the new material is that it would not require exotic ingredients. "The raw material is widely available," Ozcelik said.

The research was funded in part by the National Science Foundation, along with the Andlinger Center for Energy and the Environment. The calculations were performed on computational resources supported by the Princeton Institute for Computational Science and Engineering (PICSciE) and the Office of Information Technology's High Performance Computing Center and Visualization Laboratory at Princeton. **–Aaron Nathans**

Image courtesy of the researchers



TINY BUBBLES PLAY A BIG ROLE IN OCEANS AND WINE GLASSES

Researchers have developed a model to explain how bubbles disperse liquids, which is important for applications ranging from climate modeling to making champagne.

A day at the beach beset by heavy clouds, or the sticky heat of a salty haze can seem like the work of large, unpredictable forces. But behind such atmospheric phenomena are billions of tiny interactions between the air and microscopic drops of saltwater cast upward as bubbles on the ocean's surface burst.

Research by Luc Deike, an assistant professor of mechanical and aerospace engineering and the Princeton Environmental Institute, now describes the "jet velocity" of these droplets, or aerosols, as they occur in liquids such as seawater and sparkling wine. Deike and his colleague, Gérard Liger-Belair of the University of Reims Champagne-Ardenne, published in Physical Review Fluids a model for predicting the velocity and height of jet aerosols produced by bubbles. Their model works for bubbles from 20 microns to several millimeters in size, and in water or liquids up to 10 times more viscous.

The "jet" refers to the liquid that spurts up after a bubble has burst. Once the dome-like film of the bubble is gone, the small cavity the bubble created beneath the surface rushes to close. The bottom of the cavity rises rapidly as the sides of it collapse downward. When these forces meet, they launch a jet of water into the air that contains droplets ranging in size from one to 100 microns. A micron is one-millionth of a meter; a human hair is roughly 100 microns in diameter.

Droplets from bursting bubbles are the principal means by which aerosols are produced above the open ocean. Knowing the speed and height at which aerosols are being thrown into the air can be used for more accurate climate modeling or creating a perfect glass of champagne.

"If you know the liquid you're considering and the size of the initial bubble, we can tell you the size of the jet and the velocity of it," Deike said.

In seawater, aerosols transfer moisture, salt, and even toxins such as algae from the ocean to the air, Deike said. The researchers found that these tiny bundles of elements and organisms can soar upward at speeds as fast as 50 meters per second (111 miles per hour) where they can be transported into the atmosphere.

"I'm looking at this process to provide a better explanation of sea-spray aerosols that can be used to feed atmospheric models," Deike said. "This is something at a small scale that affects large-scale atmospheric processes, such as cloud formation and radiative balance." **–Morgan Kelly**

MARTONOSI LEADS MAJOR PUSH TO MAKE QUANTUM COMPUTING PRACTICAL

Photo by David Kelly Crow

Professor Margaret Martonosi is helping to lead a multi-institutional research team to jump-start the development of quantum computing.

Margaret Martonosi, the Hugh Trumbull Adams '35 Professor of Computer Science, has been selected to serve as a lead investigator in a $10 million National Science Foundation effort to jump-start the development of quantum computing. The multi-institutional research team will attempt to reach goals in five years that were originally thought to be decades away.

The effort, called Enabling Practical-Scale Quantum Computing, includes researchers from Princeton, the University of Chicago, MIT, Georgia Tech, and the University of California, Santa Barbara.

While standard computers use binary values of 0 and 1 as data, quantum computers rely on the inherent uncertainty of quantum particles, such as atoms or electrons, to perform calculations. Unlike bits stored in standard computers, qubits do not have a definite value until a calculation is made. This uncertainty can allow mathematicians to make powerful calculations and address problems in physics, chemistry, and other fields that standard computers cannot solve.

Martonosi said quantum computing will require software built on new algorithms as well as new hardware. Both have advanced recently, but there is an entire middle layer of interface between the two that needs to be developed. The research she and her team will be doing will seek to fill that gap. The researchers published their work in the journal IEEE Transactions on Multi-Scale Computing Systems. **–John Schoonejongen**

WEARABLE DEVICES COULD DIAGNOSE ILLNESS AS IT EMERGES

Photo by Sameer A. Khan/Fotobuddy

Professor Niraj Jha is developing software for an electronic wristband to monitor and diagnose diseases.

Princeton engineers are working to develop software that could one day use data from wearable sensors to diagnose myriad diseases in real time.

The researchers, led by electrical engineering professor Niraj Jha, reported that their system, the Hierarchical Health Decision Support System (HDSS), used biomedical data to successfully detect five diseases in simulations created from an amalgamation of patient data. The system diagnosed type-2 diabetes with 78 percent accuracy, arrhythmia with 86 percent accuracy, urinary bladder disorder with 99 percent accuracy, hypothyroid with 95 percent accuracy, and renal pelvis nephritis with 94 percent accuracy.

HDSS used publicly available, anonymized biomedical data from hundreds of patients and fed it through eight machine-learning algorithms that had been trained by the researchers to recognize typical signs of these diseases. The data consist of physiological measurements collected by commercially available medical sensors that are embedded in small electronic devices attached to hospital patients. Doctors use them to track things like blood pressure and galvanic skin response (GSR), which measures moisture in the skin to identify stress.

"This opens up the possibility for the first time that outside of a clinic, individuals can monitor whether they have developed or can develop a disease," said Jha, who developed the new technology with Hongxu Yin, an electrical engineering Ph.D. student.
–Lonnie Shekhtman

UNDER PRESSURE: FORCES FROM FLUID PLAY AN ESSENTIAL ROLE IN THE DEVELOPING LUNG

It is a marvel of nature: During gestation, multiple tissue types cooperate in building the elegantly functional structures of organs, from the brain's folds to the heart's multiple chambers. A study by Princeton researchers explored this process in lungs and offers insights into the formation of their delicately branching, tree-like airways.

Working with mouse tissue, the research team discovered that fluid pressure felt by embryonic lungs helps control the rate of development of the organ. This pressure coordinates the contraction of the smooth muscles girding the airways, which in turn spurs the sprouting of new branches throughout the fledgling lung.

The takeaway: Changes in fluid pressure can boost, or hinder, the lungs' maturation. The findings, published in the journal Development, therefore suggest a potential treatment avenue for disorders including pulmonary hypoplasia, where newborns suffer from poor oxygenation owing to underdeveloped lungs.

"Our study shows that the pressure of the fluid within the developing lung regulates the organ's rate of development," said Celeste Nelson, a professor of chemical and biological engineering at Princeton and the lead researcher. "In this way, the pulmonary pressure sends a signal to the muscles in tuning the timing of the lung's growth."

Nelson's lab is at the forefront of articulating a novel paradigm in biology in which physical forces — and not just hardwired genes running a closed developmental program — fundamentally contribute to forming complex structure. "Genes provide a blueprint for development of cells and tissues," said Nelson. "But these biological structures must still obey the laws of physics."

To exercise control over the fluids in and around a developing lung, the Princeton researchers fabricated artificial chest cavities. Made from silicone and glass, the microfluidic devices consisted of two chambers, sealed off from each other save for a connecting glass catheter, and had liquid piped in through a series of tiny rubber tubes.

Working out the complexity of making the lung in utero, researchers hope, will help not only with fetal pulmonary disorders, but also conditions that can manifest later in life, such as asthma.

"Clinical studies have suggested that many chronic diseases of the lung can be traced back to embryonic development," said Nelson. "If we understood how something as simple as fluid pressure can speed up development, we might have more sophisticated approaches to treat developmental disorders, or to engineer functional, artificial tissues."

–Adam Hadhazy

Photo by Denise Applewhite

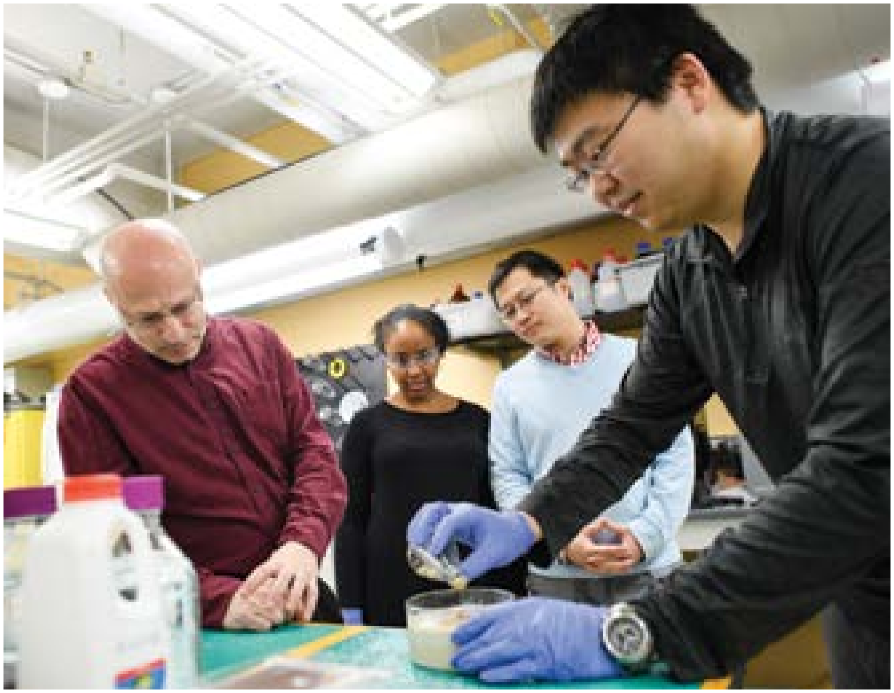
Celeste Nelson (center), a professor of chemical and biological engineering, worked with a research team including postdoctoral researchers Victor Varner and Mei-Fong Pang to examine how fluid pressure helps control the rate of development of embryonic lungs.

COFFEE PHYSICS: LAYERING IN CAFÉ LATTES YIELDS INSIGHTS FOR ENGINEERING, MEDICINE, AND ENVIRONMENT

For anyone who has marveled at the richly colored layers in a café latte, you're not alone. Princeton researchers, likewise intrigued, have now revealed how this tiered structure develops when espresso is poured into hot milk.

"The structure formation in a latte is surprising because it evolves from the chaotic, initial pouring and mixing of fluids into a very organized, distinct arrangement of layers," said Nan Xue, a graduate student in the lab of Howard Stone, the Donald R. Dixon '69 and Elizabeth W. Dixon Professor of Mechanical and Aerospace Engineering at Princeton.

Photo by Sameer A. Khan/Fotobuddy



Researchers in Professor Howard Stone's lab characterized the behavior of café latte to better understand layered fluids. From left: Stone; Janine Nunes, postdoctoral researcher; Lailai Zhu, postdoctoral researcher; and Nan Xue, graduate student.

Honing techniques for yielding sought-after layers by flowing liquids into each other could reduce costs and complexity in a range of applications.

"From a manufacturing perspective, a single pouring process is much simpler than the traditional sequential stacking of layers in a stratified product," said Stone. "In one application of this study, we are exploring the physics behind making a whole layered structure with one step, rather than one-by-one stacking of the layers."

To more precisely control their model of latte layering, Xue and colleagues opted for a stand-in recipe that would make a barista shudder: dyed water substituting for the hot coffee, and salty, denser water for the warm milk.

A panel of light-emitting diodes and a camera then illuminated and captured the movement of fluids within the concoction. The researchers seeded the mixture with tracer particles, which scattered light from a green laser beam, to further track the faux-latte's internal dynamics, a technique called particle image velocimetry. Finally, numerical simulations were run to compare the collected data with various models of the evolving system of intermixing liquids.

The overall analysis, published in Nature Communications, showed that the primary mechanism behind the layering is a phenomenon known as double-diffusive convection. It occurs when stacked-up fluids of different densities, impelled by gravity to mix their contents, exchange heat through the movement of their constituent materials. Within a given mixture, denser, cooler liquids sink, while lighter, hotter liquids rise. This sinking and rising stops, however, when the local density in a region within a latte approaches an equilibrium. As a result, the fluid there has to flow horizontally, rather than vertically, creating distinct bands, or layers.

–Adam Hadhazy

PRINCETON EXPERTS LEAD DIALOGUES ON AI AND ETHICS

Speaking to an audience of more than 500 people on campus in March, Microsoft President Brad Smith ’81 offered an optimistic vision for the potential benefits of emerging artificial intelligence technologies, but also a stern warning about their possible perils.

“Will we ensure that machines remain accountable to people? Will we ensure that the people who design these machines remain accountable to other people?” asked Smith, a Princeton University alumnus and trustee.

Smith’s talk was one of several recent talks and initiatives aimed at addressing the societal implications of emerging digital technologies, particularly artificial intelligence.

The Center for Information Technology Policy, a joint venture of the engineering school and the Woodrow Wilson School of Public and International Affairs, is at the center of these discussions. In April, the center co-hosted with the University Center for Human Values a conference titled “AI and Ethics.” The day-long event drew experts from around the world to discuss a range of topics at the intersection of computer science, public policy, political theory, and philosophy.

The two centers followed the conference by launching “Princeton Dialogues in AI and Ethics,” an ongoing series of case studies around examples of artificial intelligence and its interaction with ethics and political theory. A goal of the conference and dialogue series is to develop a set of reasoning tools that can guide practitioners and policymakers, including an ethical framework that will eventually underpin technical and legislative decisions.

One of the leaders of the effort is Edward Felten, director of the Center for Information Technology Policy and the former deputy U.S. chief technology officer in the Obama White House. The co-leader of the dialogues project is Melissa Lane, the Class of 1943 Professor of Politics and the director of the University Center for Human Values.

Photo by Andrea Kane

In a talk at Princeton on the growing role of artificial intelligence and its implications for society, Brad Smith ’81, president of Microsoft, called for people with varied backgrounds and expertise in humanities and public policy to join in discussions to ensure the fair and ethical use of the new technologies.

In opening the April conference, Lane said it was important that the effort be international in scope. The international dimension of ethics is “something practitioners in the ethics field don’t always handle very well,” Lane said. “We can talk within certain kinds of cultural and linguistic bubbles. I think the challenge of making the field of AI and ethics global, intercultural, international from its start is a really important one.” **–Steven Schultz**

Video of the conference is available at **http://bit.ly/AI-EthicsConf**
Video of Brad Smith’s talk is available at **http://bit.ly/BradSmithLecture**

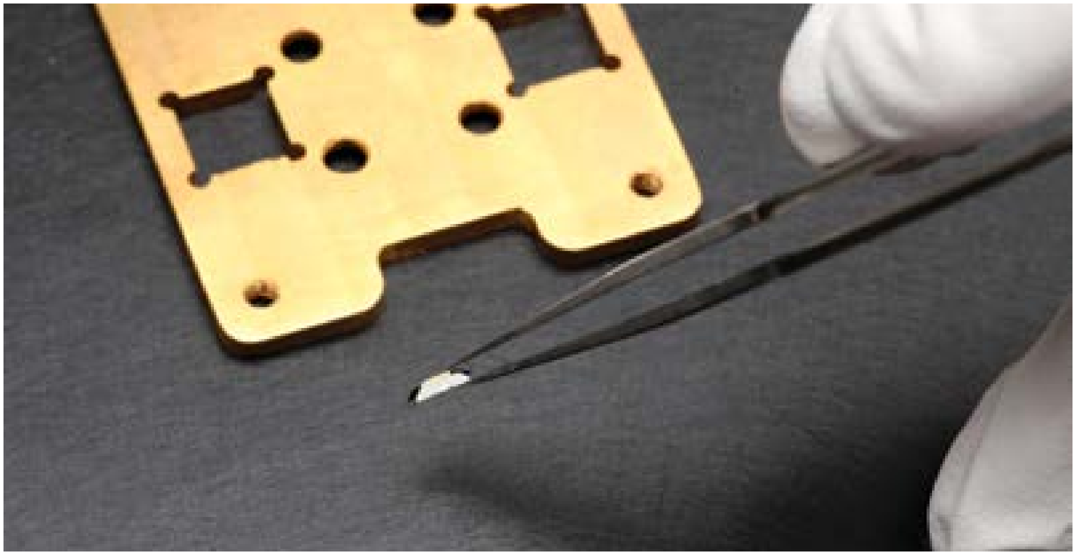


Photo by Frank Wojciechowski

DIAMONDS' FLAWS HOLD PROMISE FOR NEW TECHNOLOGIES

Princeton researchers led by Nathalie de Leon, an assistant professor of electrical engineering, are using purposeful flaws in synthetic diamonds to develop new methods in imaging and secure communications.

Despite their charm and allure, diamonds are rarely perfect. They have tiny defects that, to Nathalie de Leon, make them ever so appealing. These atom-sized mistakes have enormous potential in technologies for high-resolution imaging and secure communication lines.

"Historically, people called these defects 'color centers' because when you shine light on a diamond you see a bunch of pretty colors come back," said de Leon, an assistant professor of electrical engineering. She wants to harness the properties of these defects to image molecules and proteins.

A diamond is a tightly knit lattice of carbon atoms. By kicking out one of the carbons and adding a nitrogen atom nearby, the researchers can create a defect known as a "nitrogen-vacancy color center." The nitrogen atom and the dangling bonds around the missing carbon atom form a sort of molecule within a small area of the diamond lattice. This area of the diamond acts like a verdant oasis in the middle of a desert, displaying very different properties than the rest of the material.

De Leon is working on using a nitrogen-vacancy color center near the surface of a diamond to capture images of molecules. Interactions between the color center and the molecule can be collected and processed to make an image that is very high in spatial resolution — high enough to image a single molecule of DNA.

In a different possible use for diamond color centers, de Leon led a team that recently published a paper in the journal Science describing how they were able to store and transmit bits of quantum information, known as qubits, using a diamond in which they had replaced two carbon atoms with one silicon atom. This ability could help realize the potential of quantum computing, a new form of computing that could solve problems that are inaccessible to conventional computers.

In standard communications networks, devices called repeaters briefly store and retransmit signals to allow them to travel greater distances. De Leon's findings could form the basis of quantum repeaters for networks based on qubits. Such devices could allow information networks that are extremely secure and could allow new quantum computers to work together to complete problems that are currently unsolvable.

–Yasemin Saplakoglu

NEW PROCESS COULD CUT ENERGY DEMANDS OF FERTILIZER, NITROGEN-BASED CHEMICALS

Nitrogen-based synthetic fertilizer forms the backbone of the world food supply, but its manufacture requires a tremendous amount of energy. Now, computer modeling at Princeton University points to a method that could drastically cut the energy needed by using sunlight in the manufacturing process.

Manufacturers currently make fertilizer, pharmaceuticals, and other industrial chemicals by pulling nitrogen from the air and combining it with hydrogen. Nitrogen gas is plentiful, making up about 78 percent of air. But atmospheric nitrogen is hard to use because it is locked into pairs of atoms, called N_2, and the bond between these two atoms is the second strongest in nature. Therefore it takes a lot of energy to split up the N_2 molecule and allow the nitrogen and hydrogen atoms to combine. Most manufacturers use the Haber-Bosch process, a century-old technique that exposes the N_2 and hydrogen to an iron catalyst in a chamber heated to more than 400 degrees Celsius. The method uses so much energy that Science magazine recently reported that manufacturing fertilizer and similar compounds represents about 2 percent of the world's energy use each year.

Researchers led by Emily Carter, dean of engineering and the Gerhard R. Andlinger Professor in Energy and the Environment, wanted to know if it would be possible to use sunlight to weaken the bond in the atmospheric nitrogen molecule. If so, it would allow manufacturers to radically cut the energy needed to split nitrogen for use in fertilizer and a wide array of other products.

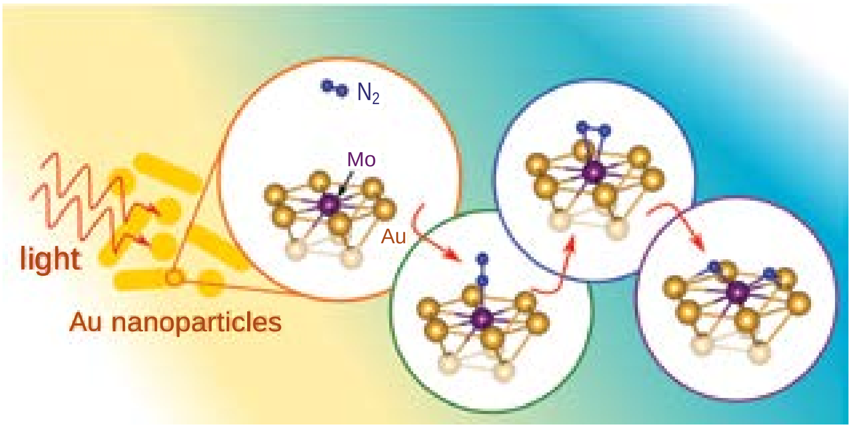
The researchers were interested in the unique behavior of sunlight when it interacts with metallic nanostructures smaller than a single wavelength of light. Among other effects, the phenomenon, called surface plasmon resonance, can concentrate light and enhance electric fields. The researchers believed it would be possible to use plasmon resonances to boost a catalyst's power to split apart nitrogen molecules. John Mark Martirez, an associate research scholar and member of the research team, said the plasmonic metal acts like a lightning rod and concentrates large amounts of light energy.

The researchers used computer simulations to model the effect of sunlight on tiny structures made from gold and molybdenum. Gold is one of a class of metals, including copper and aluminum, which can be shaped to produce surface plasmon resonances.

The researchers' calculations, published in Science Advances, indicate that the plasmon-resonance technique should be able to reduce substantially the energy needed to crack the atmospheric nitrogen molecules. Carter said the modeling indicates it could be possible to dissociate the nitrogen molecule at room temperature and at lower pressures than required by the Haber-Bosch process.

–John Sullivan

Light-driven chemical reaction



Nanostructures made from gold concentrate light energy and boost molybdenum's ability to pull apart the two nitrogen atoms in an N_2 molecule.

CYBERCRIME STOPPER: AN UNDERGRADUATE'S PROJECT PROTECTS AGAINST INTERNET THEFT

Henry Birge-Lee simply wanted to visit YouTube. Yet his high school in Los Angeles had blocked classroom computers from visiting the site on the grounds that it posed a non-educational distraction — a hardly baseless accusation, as evidenced by YouTube's millions of cat videos.

The experience sparked Birge-Lee's interest in managing the complex, occasionally treacherous interface between computers and the internet. It turned out he had a knack for the craft. His high school computer science team went on to win a national championship at CyberPatriot, a security competition held by an aerospace education nonprofit.

Now as a Princeton undergraduate, Birge-Lee has continued his streak. He is part of a research team that has pioneered a protection against potential cyberattacks.

The project focuses on "digital certificates." These electronic documents allow for secure, private communications between a user's computer and an online site. Cybercriminals have methods for obtaining fake certificates that trick users into sharing sensitive information. In their project, Birge-Lee and colleagues demonstrated a new and stealthy form of this subterfuge, and then they demonstrated new countermeasures to protect against it.

Birge-Lee learned about digital certificates in a class taught by Prateek Mittal, an assistant professor of electrical engineering and an associated faculty member in computer science. In chats about the coursework, Mittal recognized that Birge-Lee had the germ of an idea for understanding the vulnerability of certificate issuance, and securing its design. Mittal encouraged Birge-Lee to develop the idea through an independent research course in the 2017 spring semester and in his lab over the summer. Birge-Lee also collaborated with Princeton graduate students Yixin Sun and Annie Edmundson, receiving additional guidance from Jennifer Rexford '91, the Gordon Y. S. Wu Professor in Engineering and chair of the computer science department.

Shortly before submissions were due for the security and privacy conference HotPETS (Hot Topics in Privacy Enhancing Technologies), Mittal suggested it would serve as a good forum for showcasing Birge-Lee's research. Asked to do a live demonstration during the conference in Minneapolis, Birge-Lee was a bit on edge. But everything clicked on the first go. The demo was so successful that the conference organizers awarded Birge-Lee the prize for best presentation.

"Henry and his collaborators are really getting hands-on experience serving at the front lines of cybersecurity with this project," said Mittal. "I'm proud of their work and how it's already having a significant impact."

–Adam Hadhazy

Photo by Heather Evans

From left: Princeton University's Prateek Mittal, an assistant professor of electrical engineering, and undergraduate Henry Birge-Lee have developed a method to increase security for the digital certificates that authenticate websites.

SECURITY PRIVACY HUMANITY

As people around the world increasingly depend on digital technologies in their daily lives, the security and privacy of connected devices and services has become critically important. At the same time, the underlying technologies, including rapidly advancing artificial intelligence, and the way they are used for good and harm are becoming increasingly hard for average users to assess.

The articles featured here are a brief sampling of the many ways faculty and students at Princeton are working to ensure a more secure and transparent experience for technology users, from rethinking the architecture of computer chips, to discovering and fixing vulnerabilities in networks, to leading high-level policy discussions.

BRINGING A BROADER VISION TO ARTIFICIAL INTELLIGENCE

by Aaron Nathans

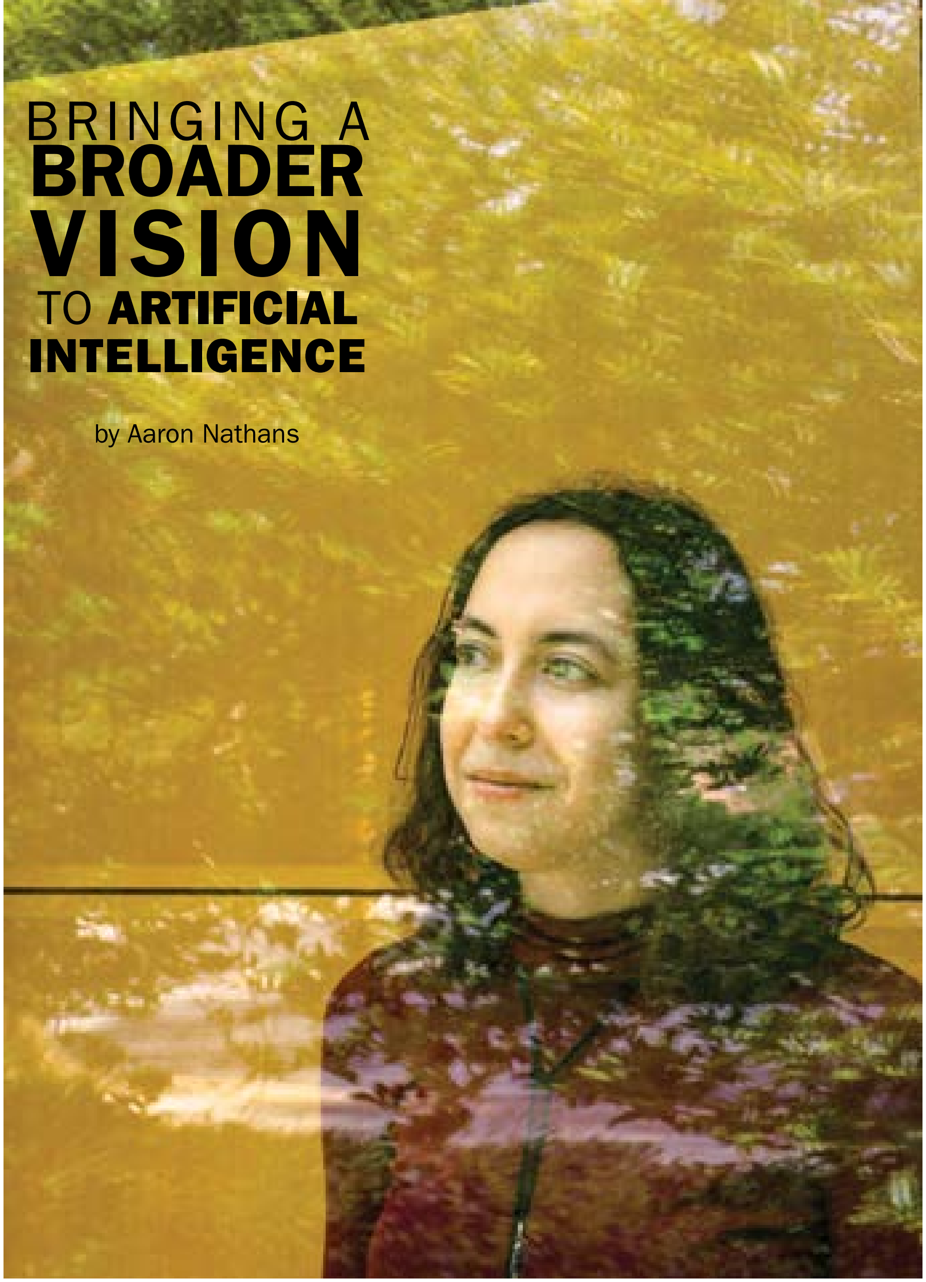


Photo by Peter Murphy

Olga Russakovsky's work is all about vision.

In the literal sense, she is creating computer vision technology that uses artificial intelligence to better identify objects and people. But Russakovsky, an assistant professor of computer science, also wants to help grow the next generation of artificial intelligence computer scientists, to expand the field's diversity of thought to better serve all of humanity.

Her drive, and that vision, helped Russakovsky recently gain the distinction of being named one of "35 Innovators Under 35" by MIT Tech Review.

Russakovsky's lab, the Princeton Visual AI Lab, is building on its success with identifying common objects and working to bring the technology to more intricate scenarios, using video. Yes, a person is sitting in a chair at a desk, but are they facing front or back? They are walking, but are they going to the ATM to withdraw some money?

Computer systems are imperfect when it comes to representing the full range of humanity, Russakovsky said. They need to be able to recognize and respond appropriately to all human faces, not just people who look a certain way, she said. She is collaborating with Arvind Narayanan, an associate professor of computer science, to study societal bias in AI, such as gender and race stereotyping.

This summer, she co-led the first Princeton edition of AI4ALL, a summer program introducing high school students to the field. She co-founded the program when she was a doctoral student at Stanford University.

The first group of incoming high school juniors were majority female, and mostly non-white. Many will end up being the first in their families to attend college. They were taught core AI concepts in an inclusive environment in an effort to build up their confidence and combat "imposter syndrome," Russakovsky said.

She once shared the feeling that she didn't quite belong, she said. "If you feel you're not quite getting the material, it's so difficult — and you look around and everyone looks different and acts different than you, that will amplify the self-doubt," she said. She pushed through with the help of role models and mentors, and she now hopes to provide that support to a new generation of AI specialists.

"When they come to college, taking programming courses, they will feel like they have a leg up," she said. "'I've seen this before… I already feel like I can do it.'" E

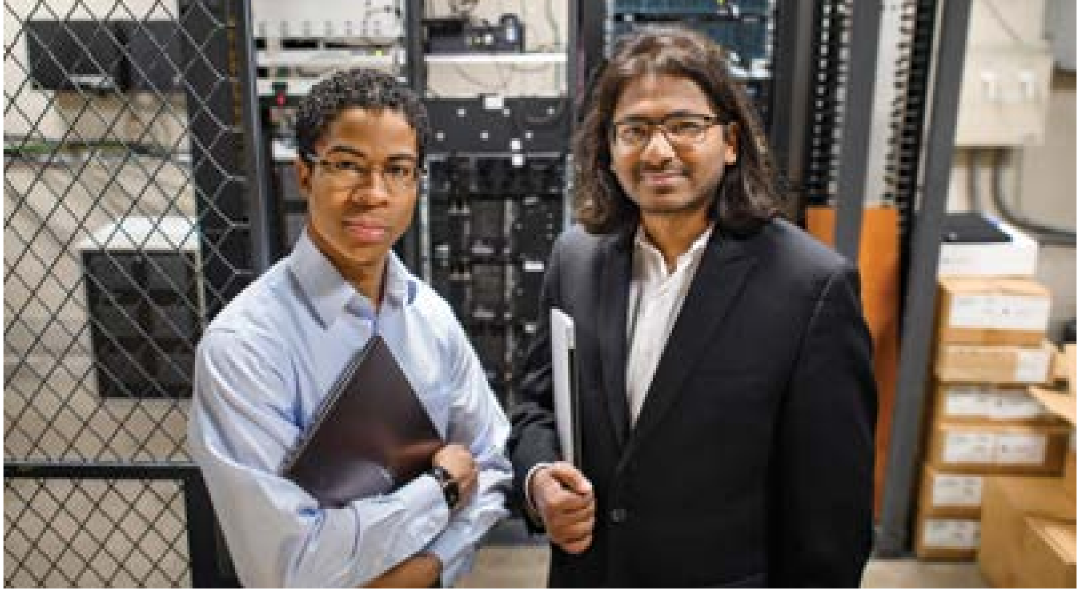


Photo by Sameer A. Khan/Fotobuddy

RECONCILING PRIVACY AND CONVENIENCE

by Scott Lyon

From left: Hans Hanley, a 2018 graduate, and Prateek Mittal, assistant professor of electrical engineering, developed a method to improve security within the anonymous Tor browser.

The 2013 revelations about government surveillance sparked an intellectual fire in Hans Hanley, who knew coming into his first year at Princeton that he was interested in cybersecurity.

What he didn't know is that before his graduation in June 2018, he would find himself at the cutting edge of online privacy. Working with Prateek Mittal, Hanley identified a new method for improving security within the Tor browser, which is designed to provide anonymity to users. His approach essentially creates a layer of digital noise that strengthens the protections offered by Tor while obscuring any information leaks from the defense mechanisms themselves.

"Everything you do online, every ad you hover over, every video you watch is recorded," he said. "It's worrying on a personal level, sure, but on a large-scale level too."

Mittal, an assistant professor of electrical engineering, focuses much of his research on protecting digital privacy. In recent work, his team and colleagues have identified a method by which someone could track a mobile phone even when the user has turned off the phone's Global Positioning System (GPS). The method uses a series of algorithms that process information such as a phone's IP address and time zone, along with data from its sensors. Among other information, phone sensors collect compass details from a gyroscope, air pressure readings from a barometer, and accelerometer data. The researchers found the system could be virtually undetectable on a phone.

In another project, with undergraduate Henry Birge-Lee, Mittal's team found vulnerabilities in the system that provides the digital certificates that ensure website authenticity (See story, page 12). By spoofing the system, someone could trick users into sharing sensitive information. The researchers identified a new and harder-to-detect form of this subterfuge — and then they unveiled new countermeasures to protect against it.

In a series of other projects, Mittal and his colleagues have recommended tools and strategies to improve Tor's ability to protect the anonymity of users and defend against attackers. They include ways to make Tor harder to attack and quicker to detect attacks when they occur.

Mittal emphasized that in the rush for convenience, it is important not to overlook privacy. Computers have opened new worlds, he said, but it is critical that we do not lose what Supreme Court Justice Louis Brandeis called "the right to be let alone."

"With careful system design and engineering, it's possible to balance privacy and convenience," he said. **E**

PRINCETON CENTER PREPARES A GENERATION OF LEADERS

by John Schoonejongen

Bridging computer science and public policy, Princeton University's Center for Information Technology Policy has established itself as a leading voice on digital technology's critical role and influence in modern society. The center hosts visiting experts and numerous events at the intersections of engineering, social sciences, law, and policy. The center's research and events have addressed issues such as election integrity, digital copyright, information security, and online privacy. It has also graduated a generation of critical thinkers who are now among the leaders in these fields.

A common thread among the alumni featured here is their work with the center's founding director Edward Felten, the Robert E. Kahn Professor of Computer Science and Public Affairs. Among numerous leadership positions, Felten served as chief technologist at the Federal Trade Commission and deputy U.S. chief technology officer under President Barack Obama.

Photo courtesy of Nadia Heninger

Nadia Heninger *11
Magerman Term Assistant Professor of Computer and Information Science, University of Pennsylvania
For Heninger, CITP played a significant role in her switch from theoretical computer science to cryptography and security. Heninger's research now focuses on how cryptography is "used and misused in real-world protocols." She has helped expose flawed cryptography and generator algorithms, and shed light on surveillance programs.

Ariel Feldman *12
Assistant Professor of Computer Science, University of Chicago
As a graduate student at the center, Feldman helped expose weaknesses in U.S. voting machines. Feldman now is working to redesign "the cloud services that we all use, both individuals and companies, so that they offer stronger security, privacy, and correctness."

David Robinson '04 and Harlan Yu *12
Co-founders of Upturn
Robinson and Yu met at CITP before founding Upturn, a D.C.-based nonprofit that works at the intersection of social justice and technology. Both said the CITP experience taught the importance of understanding how technology affects policy. "My experience [at CITP] was really the first time when I realized how, as a computer scientist, I could really make a difference in the policy world," Yu said.

Photo by Jeffrey MacMillan

Photo courtesy of Erica Portnoy

Erica Portnoy ’15
Staff Technologist, Electronic Frontier Foundation
Portnoy provides technical counsel for legal and policy projects at the Electronic Frontier Foundation. She also is developing Certbot, which is designed to help those who run websites keep their users and sites secure from network attacks. “I think that I was drawn to CITP because its topics are things that I intrinsically care about,” she said. “But it would have probably been longer before I found my way to working on them professionally if it weren’t for CITP.”

J. Alex Halderman ’03 *09
Professor of Electrical Engineering and Computer Science, University of Michigan
Halderman started Let’s Encrypt to issue free digital certificates for companies in an effort to improve internet security. Less than three years later, the nonprofit handles certificates for about 50 million websites. Halderman also has researched potential breaches in voter security related to the 2016 presidential election and testified before Congress about secure elections. “The world needs more involvement between technologists and policymakers so that we can really make use of the benefits of digital technology while minimizing the risks,” he said.

Photo courtesy of J. Alex Halderman

Dan Wallach *99
Professor of Computer Science and Electrical and Computer Engineering, Rice University
Wallach’s time at Princeton precedes the center, but he said Felten, his Ph.D. adviser, has had a profound influence on his career. Wallach’s research focuses on computer security, with some of his more visible work involving electronic voting machines, “both breaking existing ones and designing new ones that have the potential to replace them.” Wallach said Felten’s work in Washington inspired his own service with the Air Force Science Advisory Board. “It's not enough to merely do ‘good research’ when you can do research for the public good,” he said.

Photo courtesy of Dan Wallach

TRACKING THE TRACKERS

by Rachel Nuwer

Most software engineers opt for careers in the tech industry rather than academia, which makes university-based researchers all the more vital, said Arvind Narayanan, an associate professor of computer science.

"We can make the world better by working on the problems that the tech industry doesn't focus on — or even actively ignores — because those things get in the way of business interests," Narayanan said. "This includes trying to show how certain technologies being deployed are not really serving society in the way that they should, and figuring out what we can do to realign those diverging interests."

Online privacy, for example, is at odds with companies' eagerness to gather as much information as possible about their users so they can better meet users' needs — and market products to them. "Data brokers" specialize in collecting and selling personal information, from age, gender, and address to a propensity for gambling or drinking. Users typically have no idea their personal information is being scooped up, and there is a general lack of transparency about what is collected and how it is used.

Photo by Frank Wojciechowski

This is where Narayanan and his research team come in: "We want to shed light on the dark corners of online tracking," he said.

To track the trackers, he, graduate student Steven Englehardt, and postdoctoral researcher Günes Acar built a bot that visits 1 million websites each month and records everything that happens behind the scenes — from cookies to so-called fingerprinting technologies — to identify visitors. So far, they have found a number of privacy violations, including programs that either intentionally or accidentally collect sensitive information such as passwords and medical prescriptions.

"Websites can install scripts that basically act like someone watching over your shoulder and recording everything you do — every keystroke, every movement — and then send all of that information to a third party," Narayanan said.

By exposing the problem, he hopes to appeal to both policymakers and browser designers — whose technologies are essential for viewing and interacting with websites — to enact privacy protections.

"Putting the burden on individuals to protect themselves is not the best approach," Narayanan said. "There are ways to take collective action so that we don't sleepwalk into a surveillance society." **E**

TECHNOLOGY AND ETHICS INTERTWINE IN NICK FEAMSTER'S RESEARCH

by Adam Hadhazy

In our increasingly hyper-connected world, the "internet of things" is extending sensors into appliances, vehicles, and in the near future, even our bodies. The London-based data and analytics firm IHS Markit predicts that by 2030, the number of electronic devices exchanging information could quintuple from today's roughly 27 billion.

This explosion of interconnectedness exacerbates already thorny problems regarding performance, security, and ethical practices. For Nick Feamster and his research group at Princeton, the goal is to deliver the experiences users expect while safeguarding personal information.

"As more and more unmanaged, insecure devices are being connected to networks, that increases the 'attack surface,' so to speak, raising significant privacy and security concerns," said Feamster, a professor of computer science and deputy director of the Center for Information Technology Policy. "Furthermore, there must be adequate capacity on end-to-end internet paths to support the performance of the applications that we want to use."

Feamster's team is tackling these issues from first principles, collecting information that can inform real-world practices. "A lot of our projects involve the use of measurements and data in order to shed light on how networks operate and run," Feamster said.

In one, researchers are developing algorithms to enable connected devices to detect anomalies and dynamically adapt to them in real time, to help control otherwise unmanageably complex networks.

Another project concerns privacy in a connected "smart" home. The Princeton group has demonstrated how many internet-of-things devices, because they sense their environment constantly, can unintentionally record sensitive personal data, like sleeping patterns or health-related information. Any network observer, whether a benign internet service provider or a malicious hacker, could gain access to this trove. Employing a technique called traffic shaping could mitigate these risks. Sending fixed chunks of traffic to the intended recipient (say, from a smart fridge to a grocery restocking service) regardless of sensed household activity could help mask users from prying.

In all of these matters, technical capability is tied inextricably to morality — the "can" informed by the "should" — which is why Feamster is working to incorporate ethics discussions throughout the computer science curriculum. "There is a large social and political dimension to information sharing over networks," he said. "Ultimately, ethics needs to inform the technology." E

Photo by Frank Wojciechowski

Professor Nick Feamster and colleagues are using a connected "smart home" set up by Princeton to research internet-of-things devices such as refrigerators and other appliances.

SMARTPHONE SENSORS CAN **IDENTIFY PEOPLE** BY THEIR **BEHAVIOR**

by John Sullivan

Photo by Tori Repp/Fotobuddy

Ruby Lee is improving cybersecurity with deep learning.

Lee, an electrical engineering professor, is widely known for pioneering work designing security into computer hardware. More recently, she and her students are improving security using deep learning — algorithms that can discover patterns in raw data. Among projects in this area, Lee's research team has developed software that uses smartphone sensors to automatically recognize users' characteristics. While passwords can be hacked, a deep understanding of an individual's motion patterns is far more secure. Sensor-based authentication can be used together with traditional password, PIN, or biometric authentication for improved security and user convenience.

"Sensors found in every smartphone, like the accelerometer and the gyroscope, are sufficient to differentiate users with smart, machine-learning algorithms," said Lee, the Forrest G. Hamrick Professor in Engineering. "We can quickly detect a thief or impostor who is trying to use your credentials to access your online bank account, for example."

The smartphone protection is part of a wide-ranging effort by her team to address problems in computer security and computer architecture that have challenged users and designers for decades.

In April, two of Lee's graduate students, Zecheng He and Guangyuan Hu, won the Siemens FutureMakers competition with a proposal to guard power grids against online attacks. Their protection relies on algorithms that look for deviations in the normal behavior of the controlling computer system. Unlike classic countermeasures that work by identifying malware, the new system does not require knowledge about an attacker. Therefore, it works well against so-called zero-day attacks, which exploit a previously unknown security vulnerability.

"Zero-day attacks against the power grid are extremely hard to detect in real time," said Lee. "This is a huge unsolved problem."

Another graduate student, Wei-Han Lee, won a Best Paper award for work with Professor Lee and colleagues at IBM Research for showing that smartphone sensors can infer a user's handwriting patterns. The researchers demonstrated that the same sensors used to enhance security for user authentication can also be abused by an attacker to spy on the user's handwriting.

"Your smartphone sensors give a lot of information about you, and should be protected," Professor Lee said. "With advanced deep-learning techniques, we want to solve real and serious security problems in today's computing environment of smartphones, internet-of-things devices, and cloud computing." **E**

MAYER COMBINES EXPERTISE IN COMPUTER SCIENCE, LAW, AND PUBLIC POLICY

by John Schoonejongen

Talk about a tough commute.

When Jonathan Mayer ’09 joined the faculty this spring, he was conducting a seminar on information technology and public policy at Princeton while finishing his term as a technical adviser to U.S. Senator Kamala Harris. He alternated between creating political history in Washington and teaching it at Princeton.

“We were studying election security as news was breaking about Russia; we were studying data security as the Equifax story was breaking,” said Mayer, an assistant professor of computer science and public policy. “My impression was the students quite liked the very real-world context.”

Mayer graduated from Princeton in 2009 and went on to earn a doctorate in computer science and a law degree from Stanford University. Along the way, he studied government surveillance, data security, and computer crimes. With Arvind Narayanan, then a fellow Stanford graduate student and now a Princeton colleague, he wrote the first Do Not Track software and an influential position paper on internet tracking.

Since his return to Princeton this spring, Mayer has started research into three broad areas at the intersection of policy and technology.

One is the problem of fake news, those online stories passed off as legitimate journalism but which are in most cases completely fabricated. The stories often gain wide circulation on social media sites, duping readers into believing them as true. Mayer hopes to figure out ways of adapting existing techniques for identifying websites that contain dangerous malware to identify sites that traffic in fake news. Both types of websites distribute “socially undesirable content,” Mayer said.

This research, Mayer said, began as conversations with Nick Feamster, a Princeton professor of computer science. “It came straight out of the natural collaboration that happens when you stick someone who’s been dealing with the fake news problem on Capitol Hill for the past year in an office a few doors down from someone who’s been fighting malware for a number of years,” Mayer said.

In another project, Mayer plans to research foreign intelligence services’ surveillance of U.S. residents’ communications. Third, he is studying regulations dealing with corporate accountability in large data breaches.

Those projects will get him started, he said. Given the pace of change in technology, Mayer expects his research will change over the next few years.

“There’s always going to be something exciting, just because of the dynamic nature of this field,” he said. **E**

Photo by Charles Archambault

Jonathan Mayer speaks before a House committee on communications oversight in Washington this summer.

RECENT FACULTY AWARDS, PROMOTIONS, AND HONORS


Photo by Laura Pedrick

Clifford Brangwynne

CHEMICAL AND BIOLOGICAL ENGINEERING

Ilhan Aksay
Pomeroy and Betty Perry Smith Professor in Engineering

José Avalos
CAREER Award, National Science Foundation

Clifford Brangwynne
Investigator, Howard Hughes Medical Institute

Richard Register
E-Council/GEC Excellence in Teaching Award


Photo by David Kelly Crow

Sigrid Adriaenssens

CIVIL AND ENVIRONMENTAL ENGINEERING

Sigrid Adriaenssens
George Winter Award, American Society of Civil Engineers

Ian Bourg
CAREER Award, National Science Foundation

Maria Garlock
Head of Forbes College


Photo by David Kelly Crow

Maria Garlock

Amilcare Porporato
Thomas J. Wu '94 Professor of Civil and Environmental Engineering

James Smith
Hydrologic Sciences Medal, American Meteorological Society


Photo by David Kelly Crow

James Smith

COMPUTER SCIENCE

Sanjeev Arora
Member, National Academy of Sciences


Photo by Frank Wojciechowski

Sanjeev Aurora

Barbara Engelhardt
CAREER Award, National Science Foundation

Robert Fish
President-elect, IEEE Standards Association

Aarti Gupta
Fellow, Association for Computing Machinery

Kyle Jamieson
2018 SIGMOBILE RockStar Award, Association for Computing Machinery

Gillat Kol
CAREER Award, National Science Foundation

Margaret Martonosi
HPCA (High Performance Computer Architecture) Test-of-Time Paper Award, IEEE
Technical Achievement Award, IEEE Computer Society
SenSys Test of Time Award, Association of Computing Machinery


Photo by David Kelly Crow

Jennifer Rexford

Ran Raz
2018 Simons Investigator, Simons Foundation

Jennifer Rexford '91
Fellow, National Academy of Inventors

Matt Weinberg
E-Council/GEC Excellence in Teaching Award

Mark Zhandry
CAREER Award, National Science Foundation

ELECTRICAL ENGINEERING

Nathalie de Leon
CAREER Award, National Science Foundation
Early Career Award, Department of Energy

Claire Gmachl
E-Council/GEC Excellence in Teaching Award

Bede Liu
Jack S. Kilby Signal Processing Medal, IEEE

Stephen Lyon
SenSys Test of Time Award, Association of Computing Machinery

Prateek Mittal
Young Investigator Award, Office of Naval Research
IBM Faculty Award

H. Vincent Poor *77
Foreign Member, Chinese Academy of Sciences

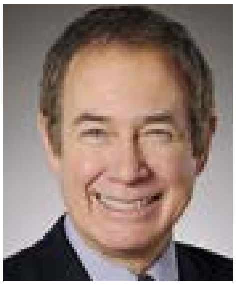


Photo by David Kelly Crow

Paul Prucnal

Paul Prucnal
Fellow, National Academy of Inventors

Alejandro Rodriguez
Participant, U.S. Frontiers of Engineering symposium, National Academy of Engineering

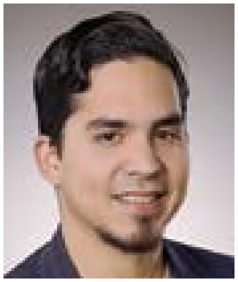


Photo by David Kelly Crow

Alejandro Rodriguez

Kaushik Sengupta
Bell Labs Prize
Young Faculty Award, DARPA
E-Council/GEC Excellence in Teaching Award
E. Lawrence Keyes, Jr./Emerson Electric Co. Faculty Advancement Award

Jeff Thompson
Young Investigator Award, Office of Naval Research

Sigurd Wagner
David Turnbull Lectureship Award, Materials Research Society

Mark Zhandry
Howard B. Wentz, Jr. Junior Faculty Award

MECHANICAL AND AEROSPACE ENGINEERING

Craig Arnold
2017 Edison Patent Award, R&D Council of New Jersey

Emily Carter
Award in Theoretical Chemistry, American Chemical Society

Irvin Glassman
Daniel Guggenheim Medal, American Institute of Aeronautics and Astronautics

Yiguang Ju
Fellow, The Combustion Institute

Jeremy Kasdin '85
Eugene Higgins Professor of Mechanical and Aerospace Engineering

Andrej Kosmrlj
CAREER Award, National Science Foundation
E-Council/GEC Excellence in Teaching Award

Chung Law
Fellow, The Combustion Institute

Howard Stone
E-Council/GEC Lifetime Achievement in Teaching Award

OPERATIONS RESEARCH AND FINANCIAL ENGINEERING

Amir Ali Ahmadi
Participant, U.S. Frontiers of Engineering symposium, National Academy of Engineering

Jianqing Fan
2018 Noether Senior Scholar Award, American Statistical Association

Samory Kpotufe
E. Lawrence Keyes, Jr./Emerson Electric Co. Faculty Advancement Award

Ronnie Sircar
Department Chair

Mengdi Wang
Google Faculty Award

SCHOOL OF ENGINEERING AND APPLIED SCIENCE

Peter Bogucki
Book Award—Popular category, Society for American Archaeology
Fellow, Society of Antiquaries of London

Photo by Frank Wojciechowski

Ronnie Sircar

TWO ENGINEERING PROFESSORS RECOGNIZED FOR OUTSTANDING TEACHING

Photo by Frank Wojciechowski

Above: Professor Richard Register received the Distinguished Teacher Award from the School of Engineering and Applied Science.

Right: Professor Stanislav Shvartsman *99 received the Graduate Mentoring Award from the McGraw Center for Teaching and Learning.

Richard Register, the Eugene Higgins Professor of Chemical and Biological Engineering, received the engineering school's Distinguished Teacher Award.

Register, who joined the Princeton faculty in 1990, investigates the synthesis, properties, and applications of complex polymeric materials. His work informs the design of materials with novel and tailored properties for uses in electronics, lightweight vehicles and structures, and separation membranes.

In presenting the award at the engineering school's Class Day ceremony, Antoine Kahn *78, the vice dean of engineering, noted that while Register chaired the Department of Chemical and Biological Engineering from 2008 to 2016, he continued to teach courses every academic year. Kahn said undergraduates appreciated Register's responsiveness and availability for extra help.

One graduate student said of Register's teaching: "For any question we raise, he not only provides explanations, but also encourages us to read more and think further."

Register received a 2008 Graduate Mentoring Award from the McGraw Center for Teaching and Learning. Earlier this year he was one of eight faculty members honored with an Excellence in Teaching Award by the student engineering councils.

Stanislav Shvartsman *99, a professor of chemical and biological engineering and the Lewis-Sigler Institute of Integrative Genomics, received a Graduate Mentoring Award from the McGraw Center for Teaching and Learning. He was one of four faculty members who received the award during the Graduate School's Hooding Ceremony June 4.

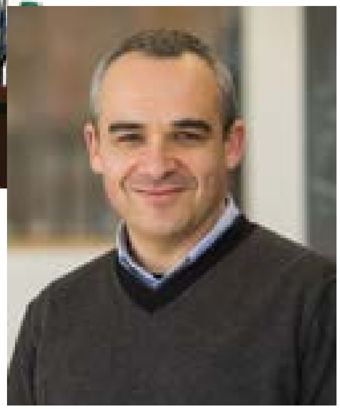


Photo by David Kelly Crow

Shvartsman, who joined the Princeton faculty in 2001, studies the dynamics of cells and living tissues, using experiments, theory, and computation to develop predictive models of biological processes.

His graduate students, who call him "Stas," said Shvartsman is exacting, but extremely supportive.

One student was reassured by Shvartsman after botching an expensive experiment. "Instead of getting impatient or angry, Stas calmly discussed a path forward and encouraged me not to get discouraged by setbacks," she said.

Former students said Shvartsman remains interested in their careers well after graduation, providing contacts and reviewing tenure applications. "I hope that over time I will be able to impact students' lives through supportive mentoring as he has done for me," said one student, now an associate professor.

CLASS DAY CELEBRATES GRADUATING ENGINEERS FOR INNOVATION, INSPIRATION, AND SERVICE

In their time at Princeton, members of the Class of 2018 helped design a method to recycle concrete while neutralizing acid discharges from mining, developed fluid flow sensors inspired by the hairs on bat wings, and tested materials for fusion power plants. The 338 engineering students in the class moved on to pursue graduate studies at schools including Harvard, Stanford, Oxford, and MIT; with employers such as General Motors, SpaceX, and Amazon; in teaching, professional sports, and the military. At Class Day ceremonies on June 4, the School of Engineering and Applied Science presented the following awards.

J. Rich Steers Award
Roan Gideon
Civil and Environmental Engineering
Matthew Romer
Mechanical and Aerospace Engineering

The Jeffrey O. Kephart '80 Prize In Engineering Physics
Lamia Ateshian
Electrical Engineering

Tau Beta Pi Prize
Sara Fridovich-Keil
Electrical Engineering

Joseph Clifton Elgin Prize
Zachariah Degiulio
Civil and Environmental Engineering
Mihika Kapoor
Computer Science

George J. Mueller Award
Emily Schneider
Chemical and Biological Engineering
Augustin Wambersie
Mechanical and Aerospace Engineering

Photos by Frank Wojciechowski

Calvin Dodd MacCracken Senior Thesis/Project Award
Tín Nguyen
Operations Research and Financial Engineering
Anna Broome
Electrical Engineering
T.J. Smith
Electrical Engineering
Daniel Stanley
Electrical Engineering
Lindsey Conlan
Civil and Environmental Engineering

Lore Von Jaskowsky Memorial Prize
Amanuella Mengiste
Chemical and Biological Engineering
Bernardo Pacini
Mechanical and Aerospace Engineering

James Hayes-Edgar Palmer Prize in Engineering
Hans Hanley
Electrical Engineering
Sally Jiao
Chemical and Biological Engineering

Award winners at the 2018 Class Day included Sara Fridovich-Keil, Hans Hanley, Lamia Ateshian, and T.J. Smith.

SENIORS BREAK NEW GROUND THROUGH INDEPENDENT RESEARCH

For Princeton undergraduates, the senior thesis is a chance to pursue original research or creative work on a topic of their own choosing. All students earning bachelor's degrees complete independent projects. Faculty advisers serve as guides for students as they learn to apply their knowledge in new ways.

For more on each of these projects, visit **http://bit.ly/theses2018**


Photo by Bill Kennedy

Katie Kennedy: Framework for a greener future
Kennedy, a civil and environmental engineering major, traveled to Meghalaya, India, to study living bridges grown from aerial roots of the Indian rubber tree. To help ensure the bridges remain a practical option in a modernizing world, Kennedy explored possibilities for refining their structures and speeding their productive growth.


Photo by Sameer A. Khan/Fotobuddy

Hans Hanley: Strengthening online security
Hanley, an electrical engineering major, identified a new method for improving security within Tor, a web browser designed to provide anonymity to users. His research borrowed from a theoretical framework used in databases, known as differential privacy, to essentially create a layer of digital noise that would obscure any information leaks within Tor.

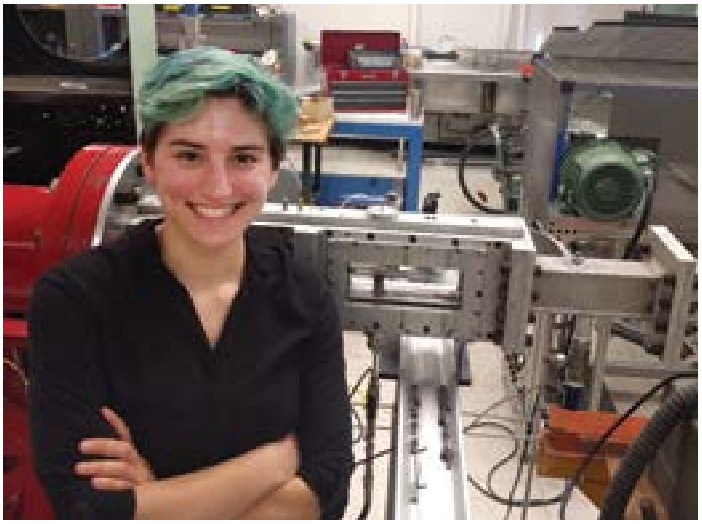
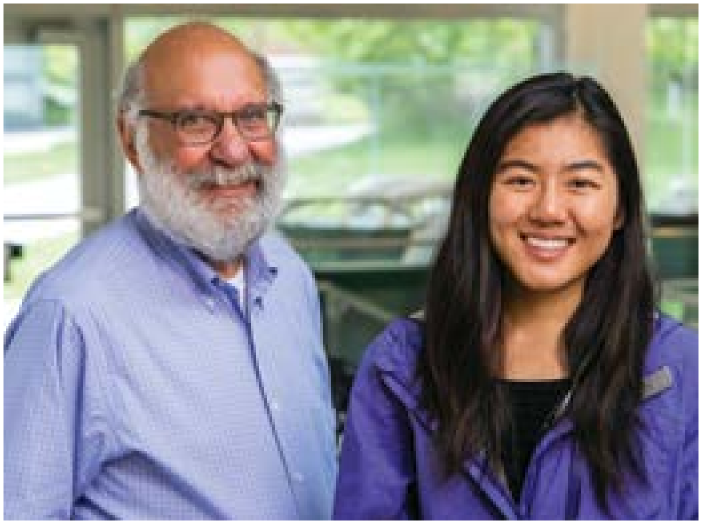


Photo by Katherine Kokmanian

Isabel Cleff: Building a better rocket
Cleff, a mechanical and aerospace engineering major, designed and tested an aerospike nozzle: a structure on the end of a rocket engine that, in contrast to the standard bell nozzle, has the potential to markedly improve the rocket's fuel efficiency.

Photo by David Kelly Crow



Lindy Zeng: Algorithms to illuminate the Amazon
Zeng, computer science major (pictured above, right, with her adviser, Professor David Dobkin), used satellite images of the Amazon rainforest to develop methods to identify features such as rivers and roads, and to track land use patterns leading to forest loss.

Photo by David Kelly Crow

Meagan Yeh: Furthering the quest for fusion energy
Yeh, a chemical and biological engineering major, addressed one of the most difficult challenges facing fusion researchers: making a reactor's walls able to withstand the heat and energetic particles from the reactions. She joined an effort testing a special type of the metal tungsten, which is extremely hard and dense and has the highest melting point of any element. Yeh (pictured above on the left) worked with Luxherta Buzi (right), a postdoctoral researcher.

Photo by David Kelly Crow

Evan Wood: Problem-solving for an uncertain world
Wood, an operations research and financial engineering major, examined methods to optimize the electricity and natural gas contracts of the multinational industrial gas company Air Liquide. Wood wrote algorithms to generate policy options designed to maximize the profitability and reliability of the company's operations within a system characterized by a high degree of randomness (or stochasticity).

Photo by Danielle Alio

SALUTATORIAN KATHERINE LIM TRANSLATES COMPUTER CODE AND CATULLUS

Katherine Lim, the 2018 salutatorian, is not one to shy away from complexity, whether she's translating a classical Latin text into English or comparing how multiple cores perform within a computer chip.

Lim, who received a BSE in computer science, began studying Latin in middle school. "Somebody had said it was very formulaic and mathematical in nature and I was like, great, that sounds fantastic, I enjoy math," she said.

She expanded her Latin studies at Princeton with courses such as "Invective, Slander, and Insult" with Robert Kaster, the Kennedy Foundation Professor of Latin Language and Literature and professor of classics. She also took "Introduction to Medieval Latin" with Brent Shaw, the Andrew Fleming West Professor in Classics, Emeritus, and senior scholar.

Lim wrote her senior project based on her work with David Wentzlaff, associate professor of electrical engineering. For the project, she worked on Wentzlaff's OpenPiton Project, a framework that allows researchers to design and test computer chips with many computational units, called cores.

Those cores can perform several streams of computation at once. Lim worked on integrating a new core into the OpenPiton framework that differs in performance and energy efficiency. "There are little cores that are energy efficient but don't run as fast, then there are big cores that run much more quickly, but they eat up a lot of energy," Lim explained.

"What I'm interested in is how you interface things at a high level," Lim said. "How you organize units, like computational units, on a chip either to make the system more friendly for programmers or to optimize it for applications or a certain way of programming."

Lim, who was awarded the Shapiro Prize for Academic Excellence and an Accenture Prize from the Department of Computer Science, will pursue a Ph.D. in computer science and engineering at the University of Washington. She received an award from the Seattle chapter of the ARCS Foundation toward her first three years in graduate school, as well as a National Science Foundation graduate research fellowship that starts next year.

Lim said that in leaving Princeton, she'll most miss friends and the graduate students in Wentzlaff's lab, who were so welcoming to her as an undergraduate in their midst.

"I think I'll miss the people," she said. "Though a lot of them are moving back to the West Coast with me." **–Denise Valenti**

GRADUATE STUDENTS HONORED FOR OUTSTANDING TEACHING

In April, two engineers were among eight graduate students who received the Graduate School's annual teaching awards in recognition of outstanding teaching.

Annabel Lemma

Lemma is a doctoral candidate in chemical and biological engineering. She was nominated for her work teaching "Introduction to Chemical and Biological Engineering Principles."

"Annabel committed an extraordinary amount of time assisting the students with the course material, and she was an approachable and valuable resource for students who had just begun the engineering curriculum or had recently declared CBE as their intended major, which are often two times of high anxiety in an undergraduate's education," said Mark Brynildsen, associate professor of chemical and biological engineering.

Students said Lemma distinguished herself as an instructor through her accessibility, her patient and detailed explanations, and her calming influence. "When I confided in her, Annabel helped me assuage my fears in adjusting at Princeton and the rigor of the engineering program," said a student. "She reassured me that everything would work itself out and explained how everyone felt overwhelmed and that I should not worry too much." Lemma expects to finish her degree in 2021.

Pierre-Yves Taunay

Taunay is a graduate student in mechanical and aerospace engineering. He served as an assistant in instruction for "Microprocessors for Measurement and Control," "Aircraft Flight Dynamics," and "Automatic Control Systems."

Michael Littman, professor of mechanical and aerospace engineering, said Taunay learned how to design the microcomputer for his class ahead of time and guided students to develop their own designs. "The trick in instruction is to guide — not do it," Littman said. "I was very impressed with his skills as an instructor."

Said a student: "I've had Pierre-Yves as a TA for two classes now, and each time, his kindness, enthusiasm, and hard work have made him stand out as an exceptional TA." Another student commented that the duration and difficulties of "Microprocessors for Measurement and Control" was "making everyone involved frustrated — except for Pierre-Yves. We wouldn't have been able to complete our project without him." Taunay expects to finish his degree in 2020.

The other winners were: Ingrid Brioso Rieumont from the Department of Spanish and Portuguese, Antonio Iannarone from the Department of Comparative Literature, Anders Nielsen from the Department of Economics, Morgan Robinson from the Department of History, Danielle Schlesinger from the Department of Geosciences, and Jessica Schwab from the Department of Psychology.

–Denise Valenti

Photo by Fotobuddy, LLC

The Graduate School has honored eight graduate students for its annual teaching awards in recognition of their outstanding abilities as teachers. Pictured from left to right are Pierre-Yves Taunay, Morgan Robinson, Danielle Schlesinger, Dean of the Graduate School Sarah-Jane Leslie *07, Antonio Iannarone, Ingrid Brioso Rieumont, Anders Nielsen, Annabel Lemma, and Jessica Schwab.

GRADUATE STUDENTS PURSUE FUNDAMENTAL PROBLEMS WITH BROAD IMPACT

Some are highly theoretical and others involve hands-on work in the lab, but the projects Princeton graduate students pursue nearly all have the goal of improving the world. Rooted in fundamental research, the projects have applications in many areas. The projects featured here range from improvements to self-driving cars, to better understanding of climate change, to cheaper and more efficient solar cells.

SRAVYA JANGAREDDY

CHEMICAL AND BIOLOGICAL ENGINEERING

Hometown:
Andhra Pradesh, India
B.Tech., Indian Institute of Technology Bombay

Polymers are plastic or rubber-like materials made of long chains of small repeating chemical units called monomers. Jangareddy investigates how to tune the properties of polymeric materials by synthesizing composites called block copolymers containing two or more distinct polymeric species. She starts with polyisoprene, a widely used rubber, and adds other polymers made of randomized sequences of monomers. She synthesizes the random copolymer block to achieve tailored architectures, sizes, and compositions, and then studies the inter-block mixing behavior via spectroscopic, thermal, and mechanical methods. One goal is creating materials with improved properties and potential applications in enhancing the material used in high-performance tires.

AMANDA SIEMANN

CIVIL AND ENVIRONMENTAL ENGINEERING

Hometown:
Naperville, Illinois
B.S., University of Notre Dame

Siemann uses satellite land-surface temperature readings to develop global datasets of the large-scale energy transfers that drive local and regional climate. She looks in particular at the energy transfer between the land surface and the atmosphere through heat conduction (sensible heat flux) and through the phase change of water from liquid to vapor in soil or vegetation (latent heat flux). Siemann validates the data against ground-based observations and explores 30-year trends in the fluxes globally and by continent, vegetation type, and climate class. These datasets are useful for benchmarking climate models at the global annual scale and the regional scale subject to the regional uncertainties and performance.

MARK MARTINEZ

COMPUTER SCIENCE

Hometown:
Marlton, New Jersey
B.A., Harvard University

Martinez seeks to steer the trajectory of autonomous vehicle research by using virtual worlds, such as those used in video games, to create data needed to make artificial intelligence in self-driving cars smarter. Training artificial intelligence algorithms takes a lot of data, but in many cases the data for self-driving cars does not exist. For instance, video data of snowy road conditions or traffic accidents are nearly impossible to collect, but virtual environments can make nearly any on-the-road scenario imaginable. Using this virtual data, Martinez is helping move the road to autonomous vehicles from the virtual world to the real one.

ROSS KERNER

ELECTRICAL ENGINEERING

Hometown:
Roseau, Minnesota
B.S., University of Minnesota Twin Cities

Kerner works at the intersection of chemistry and electrical engineering, studying a class of materials that shows promise for inexpensive, highly efficient solar cells: methylammonium lead iodide-based perovskites. To make a solar cell, perovskites need to be contacted by other materials such as a metal electrode. However, the reactivity of lead, iodine, and methylammonium (an acid) make it a challenge to fabricate stable interfaces with other materials. With collaborators in several departments, Kerner uncovers fundamental answers to explain electrochemical and photochemical phenomena at these interfaces. The results are used to direct new formulations, processes, and device architectures to improve the robustness of perovskite solar cells, LEDs, and lasers.

CHING-YAO LAI

MECHANICAL AND AEROSPACE ENGINEERING

Hometown:
Hsinchu, Taiwan
B.S., National Taiwan University

Lai's research focuses on experimental and mathematical modeling of the hydraulic fracturing process, a technique that has received significant attention for its ability to extract previously unreachable fossil fuels from underground deposits. In hydraulic fracturing, high-pressure liquid is injected into shale formations to fracture the rock and force out the fuel. However, several environmental risks have surfaced, such as stress on water supplies. Lai explores decreasing water use by fracturing with foams consisting of only 10 percent water. She aims to combine laboratory experiments with mathematical models to identify the important physics involved in foam fracturing.

ZIWEI ZHU

OPERATIONS RESEARCH AND FINANCIAL ENGINEERING

Hometown:
Tongling, China
B.S., University of Science and Technology of China

Zhu's research interests lie at the intersection of statistics, optimization, and computer science. His dissertation involves novel statistical inference algorithms for decentralized data that are ubiquitous in recommendation systems, national medical systems, and other online activities. The aim is to deliver reliable statistical efficiency with low communication overhead. To achieve this, Zhu proposed to extract informative and compact summary statistics from local data and then aggregate local information to produce the final inference results. Zhu showed that the statistical performance of the proposed distributed algorithm could match that of the centralized algorithm based on the entire data. Zhu's research promises to inspire new methods for statistical inference on big data.

Photos by Frank Wojciechowski

ALUMNI HONORED FOR ACHIEVEMENTS AND SERVICE

Francis Arnold ’79, director of the Donna and Benjamin M. Rosen Bioengineering Center at the California Institute of Technology, was elected to the American Philosophical Society. Arnold is recognized as a pioneer of directed evolution, which has led to the development of new and better enzymes for a range of products. Arnold holds a BSE in mechanical and aerospace engineering from Princeton and a Ph.D. in chemical engineering from the University of California, Berkeley.

Jeff Bezos ’86 was elected to the National Academy of Engineering “for leadership and innovation in space exploration, autonomous systems, and building a commercial pathway for human space flight.” Bezos, founder and CEO of Blue Origin and Amazon.com, earned his bachelor’s degree in electrical engineering and computer science at Princeton in 1986.


Rob Briskman

Rob Briskman ’54, president of Telecommunications Engineering Consultants and co-founder of Sirius XM Radio, was inducted into the International Astronautical Federation Hall of Fame, received the Judith A. Resnik Space Award from the IEEE Aerospace and Electronic Systems Society, and was awarded the Glenn L. Martin Medal by the University of Maryland. The awards recognized his role in the development of civilian satellite communications and broadcast systems. His BSE in electrical engineering is from Princeton, and his MSEE is from the University of Maryland.


Janice Cuny

Janice Cuny ’73, program director for computing education at the National Science Foundation (NSF), was honored with the Association of Computing Machinery Distinguished Service Award. Cuny graduated from Princeton with a BSE in electrical engineering and computer science, and earned a Ph.D. in computer science at the University of Michigan.

Yogesh Goyal *17 is among the inaugural class of Schmidt Science Fellows, a post-doctoral program focused on scientific leadership and interdisciplinary research. While a Ph.D. candidate at Princeton, Goyal received a Sir Gordon Wu Fellowship. His B.Tech. is from the Indian Institute of Technology. In November 2017, Goyal joined the Department of Chemical Engineering at the University of Pennsylvania as a postdoctoral researcher.


Leah Jamieson

Purdue University College of Engineering named the directorship of its Women in Engineering Program after **Leah Jamieson** *77. The action recognizes Jamieson’s 11 years as Purdue’s John A. Edwardson Dean of Engineering and for her encouragement of women to become engineers. Jamieson received her B.S. from MIT in 1972 and her Ph.D. in electrical engineering and computer science from Princeton in 1977. She is a member of the Keller Center for Innovation in Engineering Education Advisory Council at Princeton.

Mihalis Yannakakis *79, the Percy K. and Vida L. W. Hudson Professor of Computer Science at Columbia University, was elected to the National Academy of Sciences. The academy recognized Yannakakis’s fundamental contributions to theoretical computer science, particularly in algorithms and computational complexity, and applications to other areas. Yannakakis received his undergraduate degree from the National Technical University of Athens and his Ph.D. in electrical engineering from Princeton.


Mihalis Yannakakis

All photos courtesy of subjects

ALUMNI TAKE ON LEADERSHIP ROLES

Sally Blount '83 joined the board of Ulta Beauty as an independent director. Blount, the dean of Northwestern University's Kellogg School of Management until this year, plans to return to her faculty position at the school. Blount holds a Ph.D. in organizational behavior from Northwestern's Kellogg School and a BSE in civil engineering from Princeton.


Sally Blount

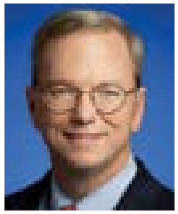
James Famiglietti *92 joined the faculty at the University of Saskatchewan and was named executive director of the university's Global Institute for Water Security. Famiglietti previously was a hydrologist at NASA's Jet Propulsion Laboratory. Famiglietti received his Ph.D. in civil engineering and operations research from Princeton in 1992, an M.S. from the University of Arizona, and a B.S. from Tufts University.

Alec Gallimore *92 was appointed to the ANSYS, Inc. Board of Directors. Gallimore is the Robert J. Vlasic Dean of Engineering at the University of Michigan. He earned a Ph.D. in mechanical and aerospace engineering from Princeton in 1992 and an undergraduate degree in aeronautical engineering from Rensselaer Polytechnic Institute.


Alec Gallimore

Richard Korhammer '88 was appointed to head the capital markets and exchange business at SenaHill Partners, a merchant bank focused on the financial technology sector. A former CEO of Lava Trading and of Airex Inc., Korhammer received his BSE from Princeton in electrical engineering and computer science.

Eric Schmidt '76 joined the Massachusetts Institute of Technology as a visiting innovation fellow for a one-year term starting the spring of 2018. He serves as an adviser to the newly launched MIT Intelligence Quest, an institute-wide initiative to advance human and machine intelligence research. Schmidt, the former executive chairman of Alphabet, Google's parent company, has a BSE in electrical engineering from Princeton and a Ph.D. from the University of California, Berkeley.


Eric Schmidt

Greg Silvestri '82 was appointed president of Glen-Gery, a manufacturer of brick and stone products and distributor of building products for residential and commercial use in the U.S. and Canada. Previously, he was president of CertainTeed, the insulation division of Saint-Gobain. Silvestri earned his MBA at the University of Virginia and his BSE in chemical engineering at Princeton.


Greg Silvestri

Carl Sparks '89 was appointed to the Avis Budget Group Board upon being nominated by SRS Investment Management. Sparks is the former CEO of Academic Partnerships and is an independent director on the board of Dunkin' Brands Group, Inc. His undergraduate degree from Princeton is in mechanical and aerospace engineering and his MBA is from Harvard.


Carl Sparks

All photos courtesy of subjects

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