EQuad News

Summer 2017
Volume 29, Number 1

PRINCETON

School of Engineering
and Applied Science

DEAN'S NOTE

Building our future

What does an L-shaped parcel on a map mean for our future? This spring Princeton University unveiled potential sites for major building initiatives, including a new location for engineering and environmental studies (see map and story, page 1). Marking a spot on a map represents an exciting point in Princeton's plan to strengthen and expand engineering. I want to take a moment to note the careful work that led us to this point as well as the challenges and breathtaking opportunities ahead.

Well before any of us contemplated maps, the University and the engineering school engaged in vigorous, extensive strategic planning. We gathered wide input, deeply considered our strengths and challenges, and distilled a compelling vision that interlocks Princeton's mission of service to humanity with its need for a world-class engineering school. Along with focusing us on initiatives such as bioengineering and data science, the intersection of which is highlighted in this magazine, the process prioritized the need for dramatically improved physical space to achieve our greatest impact.

The map, in turn, grew from Princeton's thoughtful campus planning effort. I am thrilled with the prospect of the collaborative work these new spaces will foster, but a map is not a building plan. The University and engineering school have much work going forward: We must determine how to group our academic units, how to re-use the existing EQuad, and how we will raise the substantial funds needed to make it all a reality.

If you have not done so already, I encourage you to visit Princeton's strategic planning (www.princeton.edu/strategicplan) and campus planning (campusplan.princeton.edu) websites. The stakes could not be higher. Science and technology intertwine deeply with our most pressing social, political, and environmental problems and solutions. Princeton, with its world-class engineering school embedded in a liberal arts environment, is uniquely positioned to contribute, and I look forward to joining with you in building a better future.

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


Photo by David Kelly Crow

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EQuad News is published twice a year by the Office of Engineering Communications in collaboration with the Princeton University Office of Communications.

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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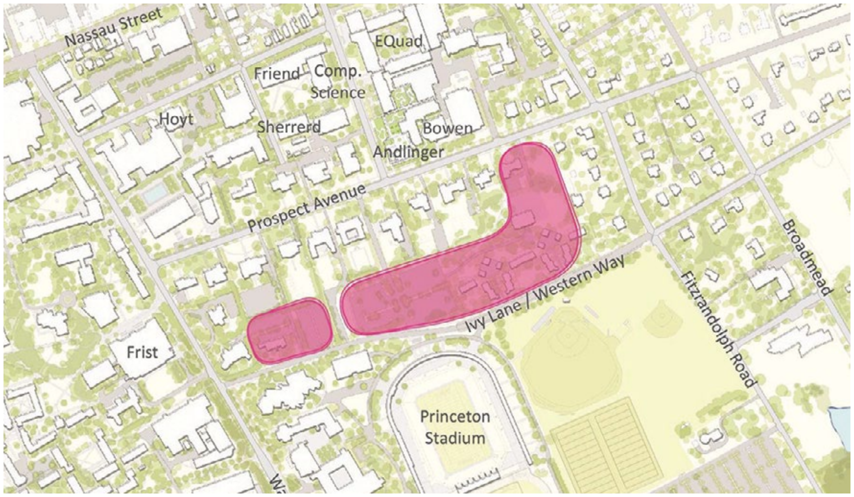


Image courtesy of Office of the University Architect

UNIVERSITY IDENTIFIES LOCATION FOR ENGINEERING EXPANSION

Princeton University has identified a potential site for the expansion of engineering and environmental studies on lands along the north side of Ivy Lane and Western Way, west of Fitzrandolph Road.

The new spaces for the expansion of the School of Engineering and Applied Science and for programs in environmental studies (including the Princeton Environmental Institute, the Department of Ecology and Evolutionary Biology, and the Department of Geosciences) would be located between the football stadium and the current Engineering Quadrangle-Andlinger Center corner of campus. This area is currently occupied by parking lots and the Ferris Thompson faculty and staff apartments, which would ultimately be relocated.

“The proposed location would facilitate regular interchange between engineering and environmental studies and would provide each of these critical and expanding fields with the new and improved space they need,” said Princeton President Christopher L. Eisgruber. The location is near existing engineering spaces that will remain in place, and other departments (including other natural science departments and the Woodrow Wilson School of Public and International Affairs) with which both engineering and environmental studies frequently interact.

“The University’s strategic planning process identified expansion of the undergraduate student body, engineering, and environmental studies as major priorities for Princeton,” Eisgruber said. “After extensive assessments and consultations with multiple constituencies, we believe our planners have identified promising locations for the facilities necessary to implement these priorities while also preserving sites and options that are essential to sustain the quality of the University’s many ongoing activities and future projects.

“We have more work to do and more consultations to conduct before making final decisions, and we welcome comments from members of our campus, town, and alumni communities as we continue to refine our planning,” Eisgruber said. **–Staff**

As part of its campus planning effort, Princeton University has identified a potential site, highlighted in red, for expanded facilities for engineering and environmental studies.

Articles in this section have been condensed from full versions available at engineering.princeton.edu.

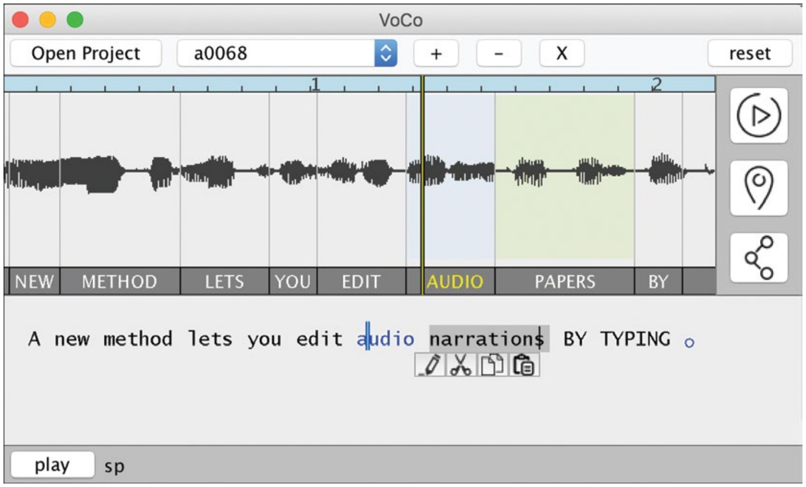
APP EDITS AUDIO LIKE TEXT, MATCHES SPEAKER'S VOICE

Anyone who ever used a typewriter will recall the difficulty of fixing a poorly chosen word — remember whiteout?

Now, technology developed by Princeton computer scientists with colleagues at Adobe Research may do for voice recordings what word processing software did for the written word.

The software, named VoCo, provides an easy means to add or replace a word in a voice recording by editing the recording's transcript. VoCo synthesizes new words in the speaker's voice even if they don't appear in the recording.

The system, which uses a sophisticated algorithm to learn and recreate a voice, could make editing podcasts and narration in videos much easier. More broadly, the technology could provide a launching point for creating personalized robotic voices that sound natural.



Technology developed by Princeton University computer scientists may do for audio recordings of the human voice what word processing software did for the written word. The software, named VoCo, provides an easy means to add or replace a word in an audio recording of a human voice by editing a transcript of the recording. New words are automatically synthesized in the speaker's voice even if they don't appear anywhere else in the recording.

"VoCo provides a peek at a very practical technology for editing audio tracks, but it is also a harbinger for future technologies that will allow the human voice to be synthesized and automated in remarkable ways," said Adam Finkelstein, a professor of computer science at Princeton who helped develop the program.

It also raises important questions about how to treat digital content that may have been altered surreptitiously to change its meaning. Finkelstein noted that, similar to how journalism has grappled with photo-editing software, society will need to learn how to address the increased ease in altering audio.

Zeyu Jin, a graduate student advised by Finkelstein, said voice conversion technologies hold promise beyond editing audio tracks. For instance, people who have lost their voices might be able to recreate them through a robotic system.

On a computer screen, VoCo augments the audio track with a text transcript and allows the user to change the audio by typing within the transcript. When the user types the new word, VoCo updates the audio track, automatically synthesizing the new word by stitching together snippets of audio from elsewhere in the narration.

"Currently, audio editors can cut out pieces of a track of narration and move a clip from one place to another. However, if you want to add a word that doesn't exist in the recording, it's possible only through a painstaking trial-and-error process of searching for small audio snippets that might fit together well enough to plausibly form the word," said Finkelstein. "VoCo automates the search and stitching process, and produces results that typically sound even better than those created manually by audio experts." **–Chris Emery**

TOOL CHECKS COMPUTER ARCHITECTURES, REVEALS FLAWS IN EMERGING DESIGN

With backing from some of the largest technology companies, a major project called RISC-V seeks to facilitate open-source design for computer chips, potentially opening chip designs beyond the few firms that dominate the space. As the project moves toward a formal release, researchers at Princeton have discovered a series of errors in the RISC-V instruction specification that now are leading to changes in the new system.

The researchers, testing a technique they created for analyzing computer memory use, found over 100 errors involving incorrect orderings in the storage and retrieval of information in variations of the RISC-V processor architecture. The researchers warned that, if uncorrected, the problems could cause errors in software running on RISC-V chips. Officials at the RISC-V Foundation said the errors would not affect most versions of RISC-V but would have caused problems for higher-performance systems.

"Incorrect memory access orderings can result in software performing calculations using the wrong values," said Margaret Martonosi, the Hugh Trumbull Adams '35 Professor of Computer Science and leader of the team that also includes Ph.D. students Caroline Trippel and Yatin Manerkar. "These in turn can lead to hard-to-debug software errors that either cause the software to crash or to be vulnerable to security exploits."

Krste Asanović, chair of the RISC-V Foundation, welcomed the researchers' contributions. He said the RISC-V Foundation has formed a working group, headed by Martonosi's former graduate student and co-researcher Daniel Lustig *15, to solve the memory-ordering problems. Asanović, a professor of electrical engineering and computer science at the University of California-Berkeley, said the RISC-V project was looking for input from the design community to "fill the gaps and the holes and getting a spec that everyone can agree on."

Photo by David Kelly Crow

Researchers including Professor Margaret Martonosi (center) and graduate students Yatin Manerkar and Caroline Trippel have developed a tool that eliminates bugs by checking computer processor designs for memory issues. The tool is already leading to improvements in a major open-source chip project.

Martonosi's team discovered the problems when testing their new system, TriCheck, that allows designers to check memory operations across any computer architecture. The name TriCheck derives from three general levels of computing: the high-level programs that create modern applications from web browsers to word processors; the instruction set architecture that functions as a basic language of the machine; and the underlying hardware implementation, a particular microprocessor designed to execute the instruction set.

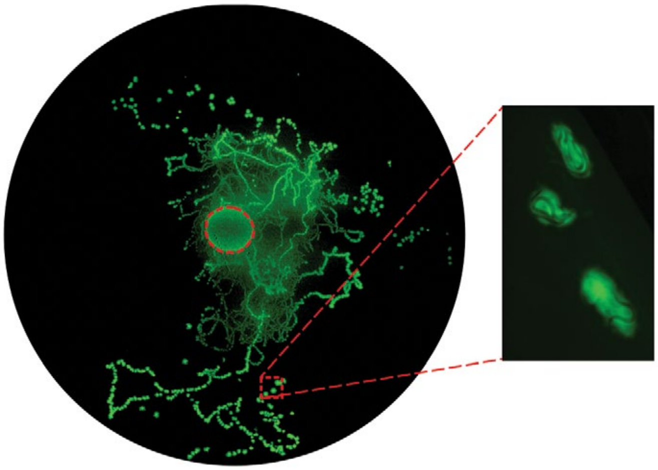
Martonosi said the goal for the TriCheck project is to stop bugs before they create problems for users.

"TriCheck is an important step in our overall goal of verifying correct memory orderings comprehensively across complex hardware and software systems," she said. "Given the increased reliance on computer systems everywhere — including finance, automobiles, and industrial control systems — moving towards verifiably correct operation is important for their reliability and safety." **–Staff**

WORMS THAT FARM THEIR OWN "MEALS TO GO": DISCOVERY ILLUMINATES COMPLEX NATURAL RELATIONSHIPS

A common roundworm widely studied for its biology and neuroscience, also might be one of the most surprising examples of the eat-local movement. Princeton researchers have found that the organisms have a sure-fire method of ensuring a steady supply of bacteria they eat — they grow their own.

The researchers reported in the Proceedings of the National Academy of Sciences that the worm, *Caenorhabditis elegans*, carries a food source, the bacteria *Escherichia coli*, along with it as it tunnels through the rotting fruit and soil in which the worms and bacteria both naturally dwell. The bacteria adhere to the worm's sticky skin as it crawls through a bacterial patch.



Princeton University researchers have found that the roundworms *Caenorhabditis elegans* have a sure-fire method of ensuring a steady supply of a bacteria they eat — they grow their own. The worms move through patches of the bacteria *Escherichia coli* (red circle), which adhere to the worms' sticky skin. As the worms move, they drop bacteria along the way to create thriving new bacterial colonies that the worms later return to "harvest" and eat (inset).

Image courtesy of Clifford Brangwynne, Department of Chemical and Biological Engineering

Studying this activity in petri dishes, however, the researchers discovered that the worms do more than simply take their meals to go. As the worms pushed through a gelatinous medium, they dropped bacteria along the way to create thriving new colonies of *E. coli* that the worms would later return to "harvest" and eat.

"It can really be best described as primitive farming," said co-author Sravanti Uppaluri, who serendipitously noticed the worms' agrarian tendencies as a postdoctoral researcher at Princeton. Uppaluri is now at Azim Premji University in Bangalore, India.

In a series of experiments, the researchers explored the ins and outs of the interspecies relationship between the worms and the bacteria. They found that new bacterial colonies formed mostly because of *E. coli* being cast off the worms' sticky, approximately 0.04-inch-long bodies. But some bacteria also passed through the worms' gut alive and undigested, establishing additional outposts.

To examine how this dynamic affected organism populations, the researchers compared normal roundworms with mutant worms whose skin is harder for the bacteria to latch onto. With the mutants, the stationary *E. coli* failed to spread and proliferate like they did in the presence of normal roundworms. With fewer bacterial crops to harvest, the population of mutant worms was smaller than that of the normal worms.

"The really interesting observation, of how worms can carry bacteria around, started the whole project," said Clifford Brangwynne, an associate professor of chemical and biological engineering, who is one of the paper's authors. "It's something very simple that countless researchers have probably seen but never really thought about."

–Adam Hadhazy

INVENTION PRODUCES CLEAN WATER WITH LESS ENERGY AND NO FILTER

The same technology that adds fizz to soda can now be used to remove particles from dirty water. Princeton engineers have found a technique for using carbon dioxide in a low-cost water treatment system that eliminates the need for costly and complex filters.

The system injects CO_2 gas into a stream of water as a method of filtering out particles. The gas mixes with the water in a system of channels and temporarily changes the water's chemistry, which causes the contaminating particles to move to one side of the channel depending on their electrical charge. Taking advantage of this migration, the researchers split the water into clean and "dirty" streams.

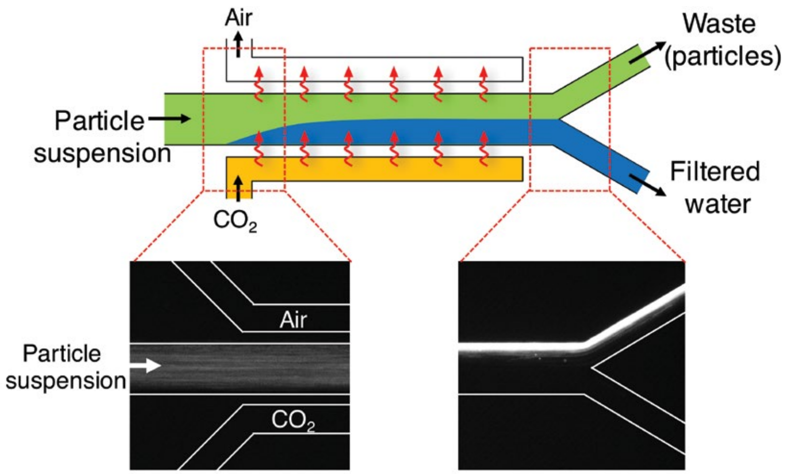
"You could potentially use this to clean water from a pond or river that has bacteria and dirt particles," said Sangwoo Shin, an assistant professor of mechanical engineering at the University of Hawaii at Manoa. Shin, the lead author of a paper describing the process, performed the research as a postdoctoral researcher in the laboratory of Howard Stone, the Donald R. Dixon '69 and Elizabeth W. Dixon Professor of Mechanical and Aerospace Engineering at Princeton.

The researchers built a laboratory-scale filter that removed particles three orders of magnitude (1,000-fold) more efficiently than conventional microfiltration systems. The system is low energy, with bottled carbon dioxide as the only moving part (besides the pump responsible for the flow), and has no physical filter or membrane that can clog or require replacement.

Carbon dioxide alters water's chemistry by making it slightly more acidic: The tart taste of carbonic acid is familiar in most sodas, and its absence is a reason for flat soda's unpleasant flavor. In chemical terms, the acidity means that when CO_2 dissolves in water it creates charged particles, or ions. One of those ions, a positively charged hydrogen atom, moves very quickly through the water solution. Another, a negatively charged bicarbonate molecule, moves more slowly. The ions' differential movement through the water creates a subtle electric field. This field draws particles in the water — which have either negative or positive charges of their own — toward one side of the water stream.

Shin said the CO_2 system could be particularly useful in the developing world because it does not require the installation and replacement of filters. The idea may be useful for portable systems. It is also relatively low cost, only requiring a canned source of carbon dioxide to use.

"It is definitely able to scale up to a hundred liters per hour, which meets a practical household standard," Shin said.
–John Sullivan



Researchers at Princeton University have found a way to clean particles from water by injecting carbon dioxide into a water channel. The gas changes the water's chemistry, which causes particles to move to one side of the water depending on their chemical charge. By taking advantage of the motion, the researchers can split the stream of water and filter out suspended particles.

Graphics courtesy of the researchers, Princeton University

INVISIBLE COATING PROTECTS ICONIC STONE STRUCTURES THREATENED BY DECAY

The stone monuments of Italy's Certosa di Bologna cemetery have stood for more than two centuries as symbols of peace and eternity. But even stone does not last forever. So Enrico Sassoni, a visiting postdoctoral research associate in civil and environmental engineering, is working to protect the marble monuments and even make them stronger.

"In spite of being apparently very durable, marble is actually sensitive to several deterioration processes," Sassoni said. "Environmental temperature variations cause the opening of cracks inside marble, and rain causes dissolution of the carved surface."

With the help of an international team, the Princeton researchers led by George Scherer, the William L. Knapp '47 Professor of Civil Engineering, Emeritus, have developed a low-cost and nontoxic treatment that might someday help art preservation and conservation specialists.

How? By applying a thin film of a calcium compound commonly found in bones and teeth. This compound, called hydroxyapatite, is formed by the reaction of a water-based phosphate salt solution and calcite, the mineral that makes up marble. The solution seeps into and binds cracks in the marble's surface. The result is a building, or work of art, that is stronger and more resistant to environmental pollution and rain, the researchers said.

What's new about the team's work is the discovery that hydroxyapatite sticks so well. "Compared to other approaches, our method also has the advantage of being based on a nontoxic solvent (water), being able to penetrate deep inside marble cracks, and reacting in just 24 hours," said Sassoni.

In September, Sassoni will return to Bologna for the final year of his project. There, he says he will test the possibility of further improving the hydroxyapatite treatment by electrodeposition — that is, assessing how well an electric current might work to deposit a thin surface layer. The Princeton researchers are also planning to start a pilot application of the hydroxyapatite treatment on some sculptures in the park of the Palace of Versailles in Paris, in collaboration with restorers and researchers in charge of the sculptures' preservation.

The team has projected that one application of the treatment has the potential to protect a marble structure for decades.

"If you can put down an invisible layer that can provide you with decades of benefit, then you can afford to treat it at that interval," Scherer said. "You wouldn't want to treat it every six months. You don't want to paint the Taj Mahal yearly. But if you could treat it, and then come back in 20 years, that would be worthwhile." **–Jeanette Beebe '14**

Using a calcium compound commonly found in bones and teeth, Princeton researchers led by George Scherer, the William L. Knapp '47 Professor of Civil Engineering, Emeritus, developed a method to protect marble structures from environmental damage. These images show decay of marble structures in the Certosa di Bologna cemetery in Italy.

Photos by Enrico Sassoni

PATTERNS BEHIND DROUGHT MOVEMENTS FOUND

A small subset of the most intense droughts move across continents in predictable patterns, according to a new study by researchers in Austria and the United States. The study could help improve projections of future droughts, allowing for more effective planning.

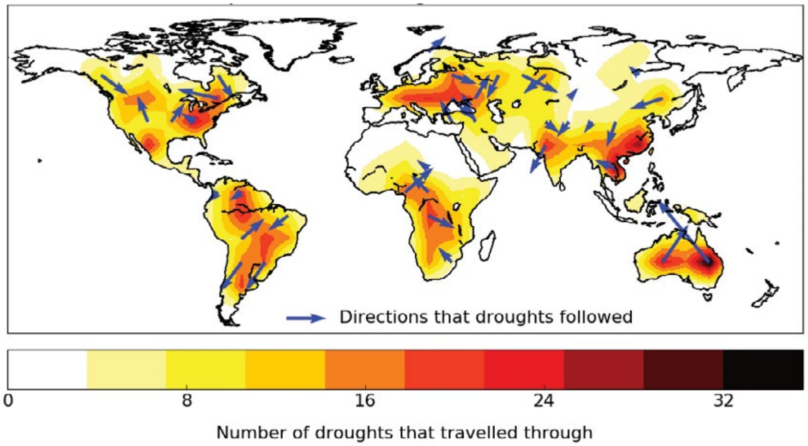
While most droughts tend to stay near their starting place, approximately 10 percent travel at least 1,400 to 3,100 kilometers (depending on the continent), the study found. These traveling droughts also tend to be the largest and most severe ones, with the highest potential for damage to the agriculture, energy, water, and humanitarian aid sectors.

"Most people think of a drought as a local or regional problem, but some intense droughts actually migrate, like a slow-motion hurricane on a timescale of months to years instead of days to weeks," said Julio Herrera-Estrada, a graduate student in civil and environmental engineering at Princeton, who led the study.

The researchers analyzed drought data from 1979 to 2009, identifying 1,420 droughts worldwide. They found hot spots on each continent where a number of droughts had followed similar tracks. For example, in the southwestern United States, droughts tend to move from south to north. In Australia, the researchers found two drought hot spots and common directions of movement, one from the east coast in a northwest direction, the other from the central plains in a northeast direction.

What causes some droughts to travel remains unclear, but the data suggest that feedback between precipitation and evaporation in the atmosphere and land may play a role.

Hot Spots Where Droughts Travelled More



While most droughts tend to stay near their starting place, approximately 10 percent travel at least 1,400 to 3,100 kilometers.

Image courtesy of the researchers

"This study also suggests that there might be specific tipping points in how large and how intense a drought is, beyond which it will carry on growing and intensifying," said Justin Sheffield, a professor of hydrology and remote sensing at the University of Southampton. Sheffield was Herrera-Estrada's adviser while serving as a research scholar at Princeton.

The study also raises the importance of regional cooperation and of sharing information across borders, whether state or national. One example is the North American Drought Monitor, which brings together measurements and other information from Mexico, the U.S., and Canada, creating a comprehensive real-time monitoring system.

The researchers said the next step for the work is to examine why and how droughts travel by studying the feedback between evaporation and precipitation in greater detail. Herrera-Estrada also said he would like to analyze how drought behavior might be affected by climate change. **–Katherine Leitzell**

Photo by David Kelly Crow

RETURNING FROM WASHINGTON, FELTEN SEEKS TECHNOLOGY-POLICY DIALOGUE

Edward Felten, the Robert E. Kahn Professor of Computer Science and Public Affairs, described how his tenure in the White House strengthened his interest in building bridges between the technical community and policymakers. Felten recently returned as director of the Center for Information Technology Policy after serving as a technical adviser during part of the Obama administration.

Edward Felten, the Robert E. Kahn Professor of Computer Science and Public Affairs, recently returned to Princeton as the director of the Center for Information Technology Policy. Felten, who studies the intersection of public policy and information technology, served as a technology adviser at the Federal Trade Commission and the White House during portions of the Obama administration. He spoke about his experience working in Washington in a recent interview. A longer version is available at www.princeton.edu/engineering.

Can you describe some of the more public issues you handled?

Probably the thing I spent the most time on was artificial intelligence and machine learning. The Obama administration started an initiative on AI and machine learning while I was there, and I was the quarterback for that. And that involved holding a series of public workshops and conferences, briefing officials in the White House and across the government, and setting up an interagency group to coordinate across the government. And then doing a couple of big public reports on AI that we published in the fall of 2016. So that was one of my work streams.

I did work on cybersecurity, both big-picture policy questions and dealing with specific events. I spent probably less time working on cybersecurity than I would have guessed going in. Probably because I don't think I fully appreciated how many other things there were that would demand my time.

To return to the artificial intelligence reports — what was the purpose of the effort?

There were several things that motivated the reports. One, AI was getting much attention in industry. Companies like Google and IBM were saying, and are still saying, that AI is the most important subject they are working on. So the intense interest from industry was driving it. Two, people from the technical community were talking about the advances in AI that were happening in the lab, tasks that 15 or 20 years ago were considered to be far in the future that AI could now do. Tasks like image recognition, which for years had been notoriously difficult: now machines are often on a par with humans. Language translation and self-driving cars are other examples.

Then there were long-term concerns about AI raised by people including Stephen Hawking and Elon Musk. The idea that one day we might make a machine of superhuman intelligence and lose control of our destiny. There had been public talk about that, and that motivates government taking a look.

All of those things led to the idea that we, the government, should look into these things to better understand how AI affects the missions of government, to crystallize everything we had learned about AI, and to focus specifically on issues that were important to public policy.

The work resulted in two comprehensive reports. What was the conclusion?

The general conclusion was that AI really is as important and transformative as many people say. AI is up there with the internet and mobile computing as a major transformative technology. There has been work on AI arguably going back to the ’40s, but it had been slow going. Around 2010, there seems to have been an acceleration as a result of a combination of big data sets, faster computers, and also improvements in AI algorithms. Some people in the field have the sense that a critical mass occurred that allowed the field to surge forward and that led to an increase in attention, research, and development.

Much of the impact is still to come. It is not a mature technology by any means. It is emerging as a new technology, and it will be some years before we see what the full impact will be.

“I think Princeton is in a good position to work on [artificial intelligence] issues because the University is very strong in all of the relevant disciplines, and we have a history of working effectively across these boundaries.”

–Edward Felten
the Robert E. Kahn Professor of Computer Science and Public Affairs

Do you expect to continue the work at Princeton?

I expect to do more work about AI and policy. We have a strong and growing AI group here at Princeton, and I hope to collaborate with them on the more policy-related questions: how to ensure that when AI is used to make decisions about people that accountability and fairness are protected? How to assess the likely impact of AI on the economy and on jobs?

We can always improve, but I think Princeton is in a good position to work on these issues because the University is very strong in all of the relevant disciplines, and we have a history of working effectively across these boundaries. There is a growing community of people from both technical and policy backgrounds working to build bridges and ensure that technical thinking is built into policy and that designers of new technology think about the policy implications. One of the main things I did in government, and I am trying to do at Princeton, is to increase that dialogue. **–John Sullivan**

SELF-POWERED SYSTEM MAKES SMART WINDOWS SMARTER

Below: Princeton engineers invented a window system that could simultaneously generate electricity and lower heating and cooling costs. The team, led by Professor Yueh-Lin (Lynn) Loo, center, includes graduate students Nicholas Davy, left, and Melda Sezen-Edmonds. Behind them is a clean room at the Andlinger Center for Energy and the Environment, where Loo is the director.
Right: Graduate student Nicholas Davy holds a sample of the special window glass, which harvests one portion of the light spectrum to control other parts of the spectrum.

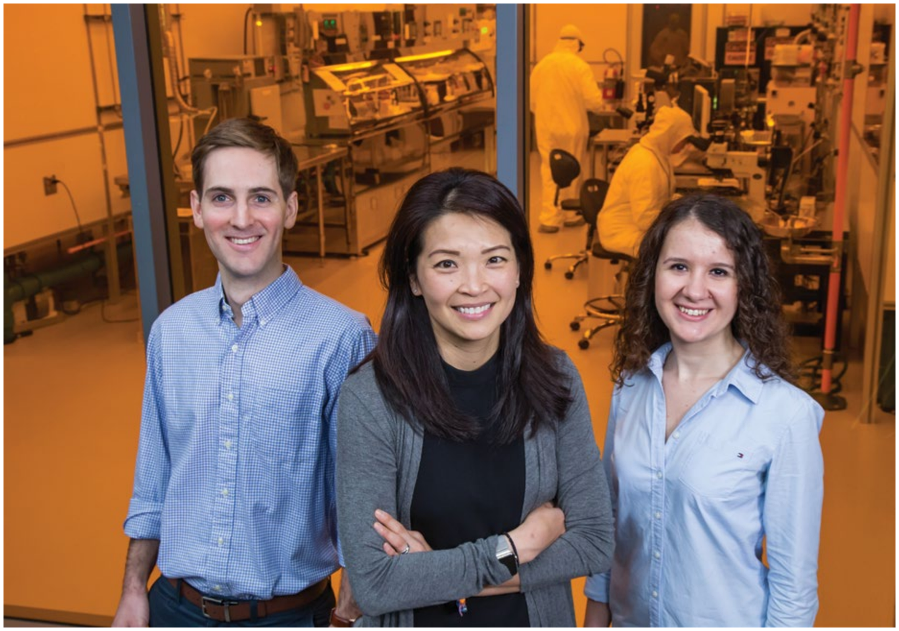
Applying a new solar cell technology that harnesses an invisible part of the light spectrum, Princeton engineers have developed a new type of "smart window" that could save heating and cooling costs by changing tint.

Researchers have long pursued smart windows that let in more or less light and heat as needed, with potential to save 40 percent in a building's heating and cooling costs. However, most of these require electricity for operation, so they are relatively complicated to install in existing buildings. The new technology invented at Princeton is self-powered and promises to be inexpensive and easy to apply to existing windows.

This system features transparent solar cells that selectively absorb near-ultraviolet (near-UV) light and convert it to electricity.

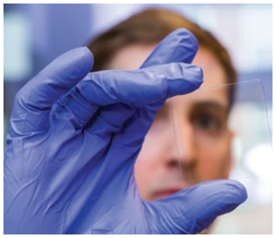
"Sunlight is a mixture of electromagnetic radiation made up of near-UV rays, visible light, and infrared energy, or heat," said Yueh-Lin (Lynn) Loo *01, director of the Andlinger Center for Energy and the Environment, and the Theodora D. '78 and William H. Walton III '74 Professor in Engineering. "This new technology is actually smart management of the entire spectrum of sunlight."

Photos by David Kelly Crow



Loo's team published the results June 30 in the journal Nature Energy.

Nicholas Davy, a doctoral student in Loo's group and the paper's lead author, said that the Princeton team's aim is to create a flexible version of the solar-powered smart window system that can be applied to existing windows via lamination.



"Someone in their house or apartment could take these wireless smart window laminates — which could have a sticky backing that is peeled off — and install them on the interior of their windows," said Davy. "Then you could control the sunlight passing into your home using an app on your phone, thereby instantly improving energy efficiency, comfort, and privacy."

Davy and Loo started a company, Andluca Technologies, based on the technology. They also are exploring other applications for the transparent near-UV solar cells, which might power internet-of-things sensors and other low-power consumer products.

"It does not generate enough power for a car, but it can provide auxiliary power for smaller devices, for example, a fan to cool the car while it's parked in the hot sun," Loo said.

Support for the project was provided in part by the National Science Foundation and the Wilke Family Fund administered by the School of Engineering and Applied Science.

–Sharon Adarlo

DAUGHTER HONORS FATHER'S QUEST TO SOLVE THE PROBLEM OF TURBULENCE

Turbulence jostles a rough flight, mixes rivulets in a stream, billows smoke into mysterious swirls. Though ubiquitous in nature, these chaotic movements of fluids have defied thorough scientific description for centuries.

The late Sin-I Cheng, a longtime professor of mechanical and aerospace engineering, studied turbulence with a patient passion, bringing clarity and rigor to the irregular and chaotic. His lifelong quest was to find an analytical theory of turbulence, to understand and predict it.

"Everything in life is some form of chaos presenting itself to us," said Irene Cheng, one of Cheng's four children. "In his quiet way, he always believed in that, and he would look at all facets of life through that lens."

Cheng recently made a gift to name a professorship in engineering in honor of her father, who was a faculty member at Princeton for over four decades. He died of cancer in 2011, at the age of 89.

"My father had a deep commitment to the power of the intellect," said Cheng. It was this ethos — this "take a chance" culture at Princeton, she said, that her father found so valuable and embracing. "He would never have dreamed of being anywhere else, doing anything else," she said.

At home and in the classroom, her father delighted in following a thought as far as it could go, exploring all paths without judgment. There was a lightness to him, she remembers, yet he maintained a wholly rigorous approach. A more "robust" answer might be hiding at the end of a "zig-zag line," she said, no matter how long that might take. "He cared only about finding an answer, or even the answer, if you can be so lucky."

Cheng said her father's time at Princeton, where he earned his Ph.D. in aeronautical engineering in 1952, offered him a unique opportunity to pursue that approach, and commit to a long career of creative and rigorous study.

"They were willing to make a bet on him, a clearly brilliant but otherwise unknown student from war-torn China. They made him feel at home, and gave him freedom to spend a lifetime going against accepted wisdom," she said.

Cheng said she hopes her gift to Princeton will build on that legacy, especially for scholars who are committed to tackling "big, long-term problems." "It's about not being held back by convention or the short-term, and instead opening up what's possible," she said. **–Jeanette Beebe '14**

Sin-I Cheng, a professor of mechanical and aerospace engineering, emeritus

Photo courtesy of Irene Cheng

ART OF SCIENCE COMPETITION HIGHLIGHTS INTERSECTION OF DISCIPLINES

When graduate student Tsung-Lin Hsieh created the winning image in this year's Art of Science exhibit, he was not trying make art: he was trying to understand storms.

Hsieh, a third-year student in atmospheric and oceanic sciences, first tried to use simple graphs to describe precipitation's role in storm intensity, but knew he was not capturing the full meaning of his data. So he turned from two dimensions to three, creating essentially a digital diorama of how clouds and temperature fronts and winds occupy a space equivalent to the Eastern United States. His effort, now displayed along with 44 other images selected for the exhibit, depicts a gnarled two-legged column of clouds rising through undulating sheets and slashed by a green swooping line.

Ultimately, the visualization helped Hsieh come up with a theory of how rain affects overall storm intensity, which he is incorporating into an upcoming paper.

"It gave me a better intuition of the structure of a winter storm," he said.

For at least one of the judges, it was the boldness of that bright green line, which represents the movement of the jet stream as it encounters a storm, that sealed the image's status as the visually strongest entry. Emmet Gowin, a professor of visual arts in the Lewis Center for the Arts, emeritus, who served as a judge, said the best of the works transcend their origins.

Art of Science, organized by the School of Engineering and Applied Science, is a competition open to researchers across the University and alumni, celebrates visually compelling images and videos created in the process of research. This year's competition, which opened May 5 and is on display at Princeton's Friend Center, drew more than 160 submissions. The finalists were chosen for their aesthetic excellence, scientific or technical interest, and universal appeal. Besides Gowin, the judges included James Steward, director of the Princeton University Art Museum, and Jeffrey Whetstone, photographer and professor of visual arts in the Lewis Center for the Arts.

"Art and science have much in common and much to say to each other," said Emily Carter, dean of engineering, in presenting the winners at the opening reception. "Both cross cultures, languages, and age groups. Both fields are essential expressions of human creativity."

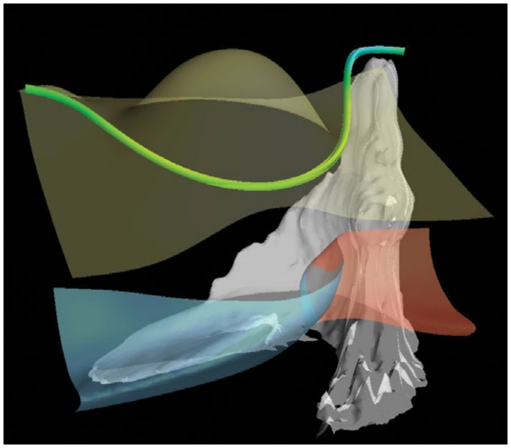
An online gallery of the images is available at artofsci.princeton.edu.

–Steven Schultz

Face Warp

Ohad Fried *17
Department of Computer Science

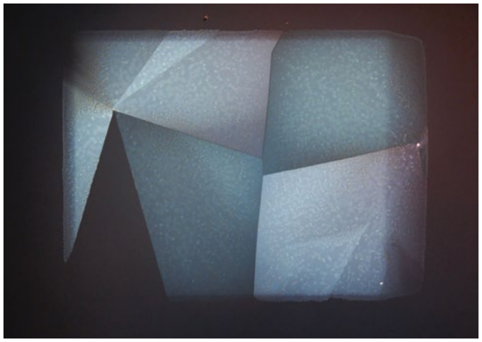
This work depicts a warp field used to edit a portrait photo. Color indicates direction and saturation indicates magnitude. The warp field is used to change the pose of the head and the location of the camera, in post-processing after the photo is taken.



Clash of Air Masses

Tsung-Lin Hsieh (graduate student)
Program in Atmospheric and Oceanic Sciences

Extratropical cyclones form when the warm air in the south collides and mixes with the cold air in the north. This 3-D visualization shows a simulated extratropical cyclone viewed from southwest to northeast, with warm air moving north behind the red surface and cold air moving south behind the blue surface. Deep clouds form along the warm airflow and produce rain. The cyclone is coupled with the jet stream in the upper troposphere, meandering along the yellow isentropic surface.



Crystalline Mondrian

Michael Fusella (graduate student)
Department of Electrical Engineering

This image shows a patterned rubrene crystal thin film about 20 nanometers thick. Each single-colored area is a single crystalline domain. The color differences are a result of in-plane molecular rotation that causes constructive or destructive interference in the polarized light image.

COMPUTING and BIOLOGY

A frontier with a history

Understanding how mechanical forces build the tissues of our bodies.

Mapping the networks of neurons that give rise to thoughts within our brains.

Revealing the genetic links to disease.

As witnessed in this issue, bioengineering — and in particular, the connections between biology, engineering, and computation — is experiencing a resurgence on Princeton's campus. Yes, a resurgence. In the 1970s, before the certificate system as we know it today was introduced, undergraduate students had the opportunity to identify themselves with a topical program in engineering, through which they could construct an independent educational plan of coursework and research that borrowed from offerings across engineering and the natural sciences. And, in its prescience, Princeton had a topical program in bioengineering, which included coursework such as "Computer Applications to Medicine" and "Laboratory in Engineering Physiology," as well as research projects on biological oscillations, biomaterials, and neuronal control systems, among others. All this a decade before the birth of the Department of Computer Science in 1985.

Fast forward 40 years, and the innovative potential presaged by that early bioengineering topical program is becoming a reality. Over the past couple of decades, biology has transformed into a quantitative and quantifiable discipline, one that requires an appreciation for mathematics. Princeton has led the way in uncovering the basic mechanisms that control life at the levels of molecules, cells, tissues, and populations of organisms, with its pioneering research programs in molecular biology, genomics, and neuroscience. These research efforts have dovetailed with advances in sensing, imaging, and computing led by engineering faculty.

Now, this exciting era of quantifiable biology is inspiring a new generation of faculty to define the innermost workings of life — and to begin to engineer living systems in a purposeful way. Today's undergraduate students have even greater opportunities in independent research at the interface between engineering and biology. The chemical reactions inside cells can now be controlled with light, which has implications for neuroscience and psychology as well as for creating light-activated living machines. The billions of base-pairs of information obtained from DNA sequencing can now be interpreted through advances in computing, with the potential for breakthroughs in diagnostics, therapeutics, and personalized medicine. Genetic circuits can be reprogrammed to coax cells to manufacture high-commodity goods including biofuels and pharmaceuticals. And more!

Princeton is leading the way in defining bioengineering at the intersection of computation, built upon the fundamentals of biology with the potential for far-reaching applications that will change the way we live our lives. Imagine the research opportunities that will be available to students in 40 years. **E**

Celeste Nelson *is a professor of chemical and biological engineering*

DATA PINPOINT ORIGINS OF **DISEASE**

by John Sullivan

Modern medicine is good at understanding the cause of disease, whether viral, bacterial, or immunological. But narrow questions — why illness strikes a person at a specific time and in a specific way — remain a mystery.

"Understanding disease, really understanding it, requires math and statistical modeling, because disease risk and the way disease is mediated is different for each individual," said Barbara Engelhardt, an assistant professor of computer science. "Everyone gets sick for different reasons."

When the human genome was mapped in 2003, it was hailed as the start of an era of personalized medicine in which doctors would tailor treatments based on patients' DNA. Reality turned out to be far more complex. Interpreting the genome isn't like reading sheet music; it is more like listening to a dozen orchestras simultaneously playing different symphonies.

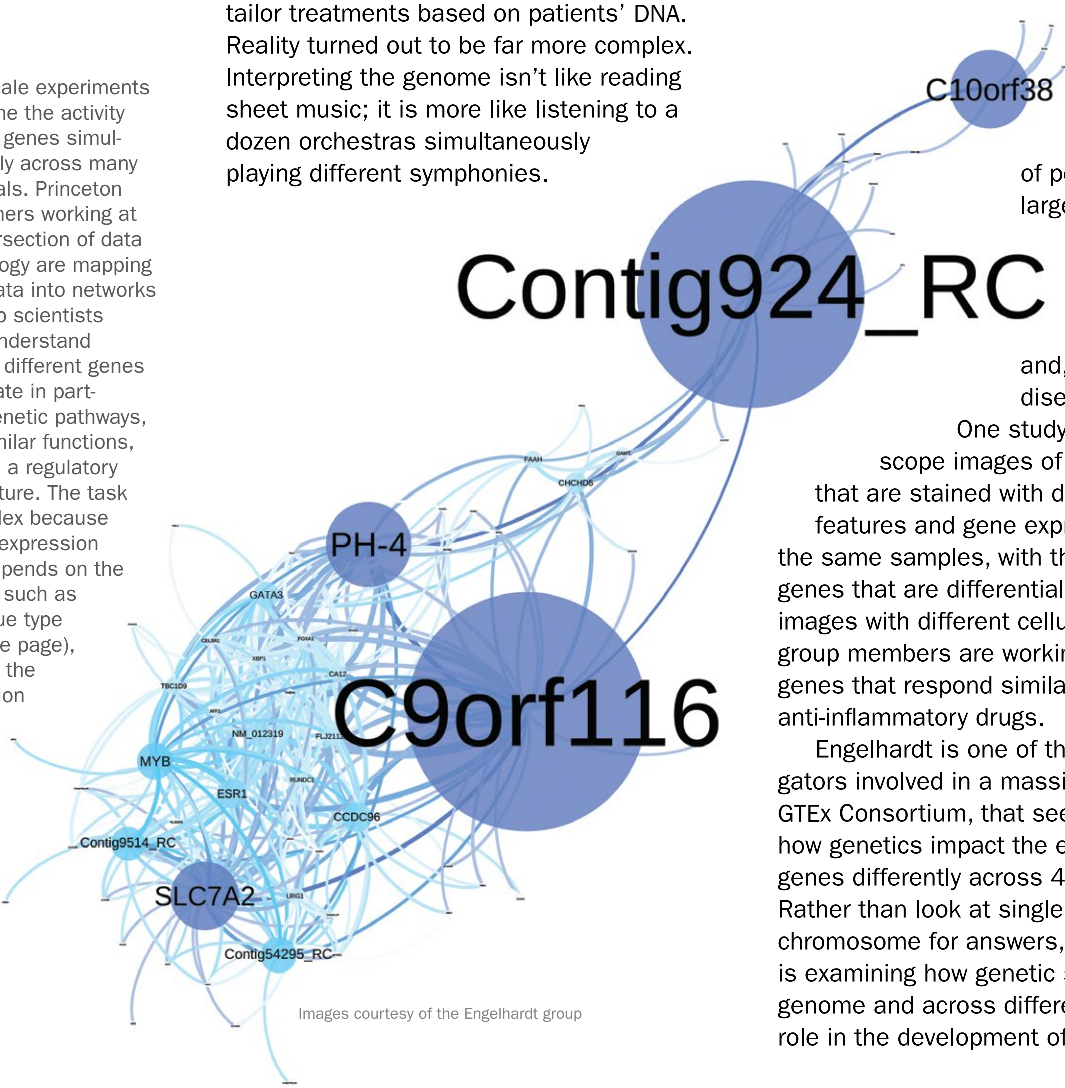
Engelhardt's lab sorts the music from the noise.

"We want to understand the genetic and molecular basis for disease to create patient-specific therapies, whether that means drug design or treatment in the hospital," she said.

To that end, the lab is balancing a number of different projects. Several deal with the complex and knotty data that often emerge from genetic studies: Some in Engelhardt's group are working to boil down cases that involve a small number of people and a very large number of genetic markers to find out which genetic variants regulate cellular state and, ultimately, disease risk.

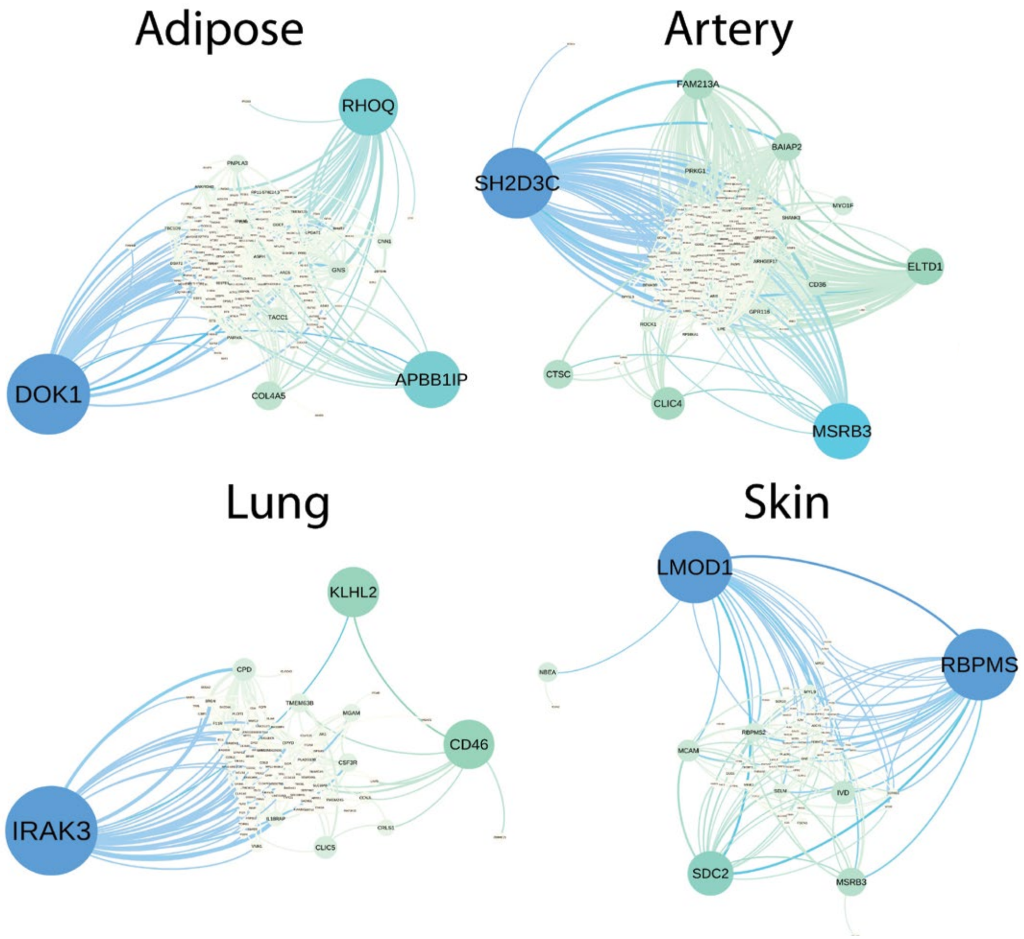
One study involves microscope images of diseased tissues that are stained with dyes to highlight key features and gene expression data from the same samples, with the goal of finding the genes that are differentially expressed across images with different cellular structures. Other group members are working to find clusters of genes that respond similarly after exposure to anti-inflammatory drugs.

Engelhardt is one of the principal investigators involved in a massive study, called the GTEx Consortium, that seeks to understand how genetics impact the expression levels of genes differently across 44 human tissues. Rather than look at single locations along a chromosome for answers, the consortium is examining how genetic sites across the genome and across different tissues play a role in the development of disease.



Large-scale experiments determine the activity of many genes simultaneously across many individuals. Princeton researchers working at the intersection of data and biology are mapping these data into networks that help scientists better understand whether different genes participate in particular genetic pathways, have similar functions, or share a regulatory architecture. The task is complex because genetic expression often depends on the context, such as the tissue type (opposite page), in which the expression occurs.

Images courtesy of the Engelhardt group



Other students in the group are finding patterns in medical data that hospitals use to monitor patients. They are trying to determine whether it is possible to look at patient data over time, including white blood cell counts and blood pressure, and determine which patient is likely to develop sepsis or other serious conditions.

"We are trying to build models to determine why each person is getting sick. The origin of disease could be at the genetic level, the molecular level, or the environmental level, or some combination of those," Engelhardt said. "We are looking for patterns in the data so we can exploit those patterns to find ways to improve health." E

Photo by Sameer Khan/Fotobuddy

Computer scientist Barbara Engelhardt is one of the principal investigators participating in a multi-institution project funded by the National Institutes of Health to understand the varying activity of genes across 44 human tissue types.

SOLVING THE ENIGMA OF TISSUE DEVELOPMENT

by Adam Hadhazy

Celeste Nelson, left, of chemical and biological engineering, collaborates with Andrej Kosmrlj, right, of mechanical and aerospace engineering, to understand the physical forces that cause structures, such as organs, to form during embryonic development. The work involves a mix of experimental work and computational and theoretical modeling of data.

It is nothing short of astounding how intricate creatures such as ourselves can develop from a single egg cell, barely the size of a grain of sand.

Scientists have only a broad outline of this transformation. As an egg rapidly divides, its legions of daughter cells begin to self-organize, layering and folding into tissue structures known as organs. Before a fetus's first trimester is over, proliferating cells have arranged themselves into every organ, as varied as the wrinkled brain, the chambered heart, and the textured skin.

To unravel this daunting question of tissue growth and structure development, Princeton's engineering labs are pooling their expertise. The insights gained could usher in new treatments for tissue malformations and aid in creating artificial organs, suitable for pharmaceutical testing or even transplantation.

"One person, or even one whole lab, cannot do this sort of project on tissue structure development alone. You need to combine forces," said Andrej Kosmrlj, an assistant professor of mechanical and aerospace engineering and a member of the Princeton Institute for the Science and Technology of Materials.

Photo by David Kelly Crow

The Kosmrlj group at Princeton works on theoretical and computer-based modeling of how materials, both living and non-living, assume certain shapes and structures. Two students of Kosmrlj's are wielding his group's tools in collaboration with other Princeton labs.

This summer the students are working with Celeste Nelson, a professor of chemical and biological engineering. Nelson's lab has explored organ development, especially that of the lung, for the better part of a decade.

"Amazingly, in 2017, the development of the lung — of any organ, really — is still a black box," said Nelson.

Lungs are organized like a tree, where a main trunk (actually a hollow tube) splits off into thick branches and progressively thinner twigs. All told, mature lungs have eight million such branches, harvesting oxygen and expelling carbon dioxide waste exchange across a surface area the size of a tennis court.

In every individual of a given species, this tubular tree is identical. The branches form at set locations, with precise geometries, all during a tight time window when the organ is developing in utero. From research on humans' fellow mammals, the Nelson lab has determined that so-called epithelial tissue, which lines the frond-like airways, cannot spread correctly without the girdle-like action of an encircling layer of smooth muscle cells.

To investigate further, research specialist Katie Goodwin in Nelson's lab is obtaining new time-lapse images of fetal mice, watching as their lungs build up branch by branch. Meanwhile, Kosmrlj's students are devising a mathematical framework to describe and predict how this branching proceeds. Getting a handle on the process in mice should inform concepts of human lung development.

"It's the hope of any engineer: If you understand what's required for something to be built, then you should be able to build it yourself," said Nelson.

Besides growing artificial organs, the work could provide clinical insights for neonatal intensive care units. A large portion of babies admitted there are born too early, before their lungs fully develop, or have structural defects preventing proper oxygenation.

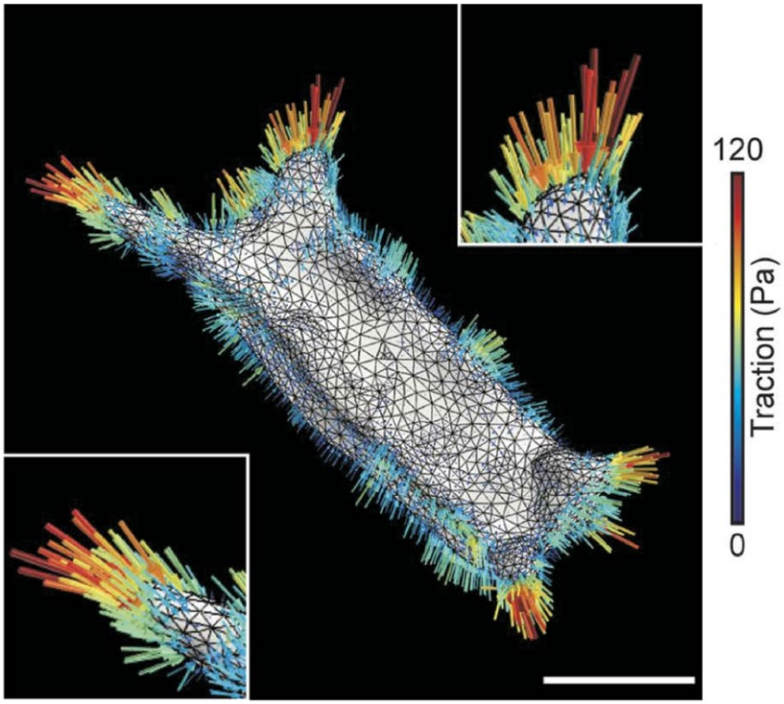
"If we understand what goes wrong," Kosmrlj said, "we can learn how to fix it."

Last summer, Kosmrlj assisted on another tissue development project with Jan Rozman, a visiting student from the University of Ljubljana in Slovenia, alongside Stanislav Shvartsman *99, a professor of chemical and biological engineering and the Lewis-Sigler Institute for Integrative Genomics at Princeton.

The project focused on fruit fly egg chambers, which develop into single eggs ready for fertilization. First, a lone cell divides, maintaining a narrow connection to its daughter cell. The conjoined units undergo additional divisions, resulting in 16 cells organized into a tree-like cyst. Next, the cells absorb nutrients, unequally swelling up like balloons to 1,000 times their original size. A protective layer of epithelial cells surrounding the 16 cells must itself grow in number, from about 50 originally to 1,000, to accommodate the interior cells' expansion. In rapid order, 15 of those 16 cells — dubbed nurse cells — then squeeze their contents into an ultimate, large egg cell.

Working together with Jasmin Imran Alsous, a graduate student in the Shvartsman laboratory, Rozman is continuing to craft a theoretical model for this end-stage, elucidating one of the egg chamber's elaborate yet tractable behaviors.

The overall interactions between the chamber's two divergent cell types mirror the developmental coordination displayed in mammalian lungs and many other organs. By understanding select systems in depth, the whole mystery of development may be laid bare.



In one study from Nelson's lab, researchers investigated how cells collectively migrate across tissues by mapping the traction forces between the migrating cells and the surrounding collagen matrix. Blue represents the least traction and red the most. The movement of cells is important in understanding healthy organ development, wound repair, and the spread of cancer.

"Growth, patterning, and size changes are highly conserved across the animal kingdom," said Shvartsman. "It's something that nature learned to do once and then adapted in different circumstances."

"There's only a handful of ways that tissues can build themselves into complex structures," said Nelson. "By comparing and contrasting between species, we can learn a lot about the common motifs of development." **E**

LIGHT AND MATH REVEAL STRUCTURE IN THE 'CELLULAR SEA'

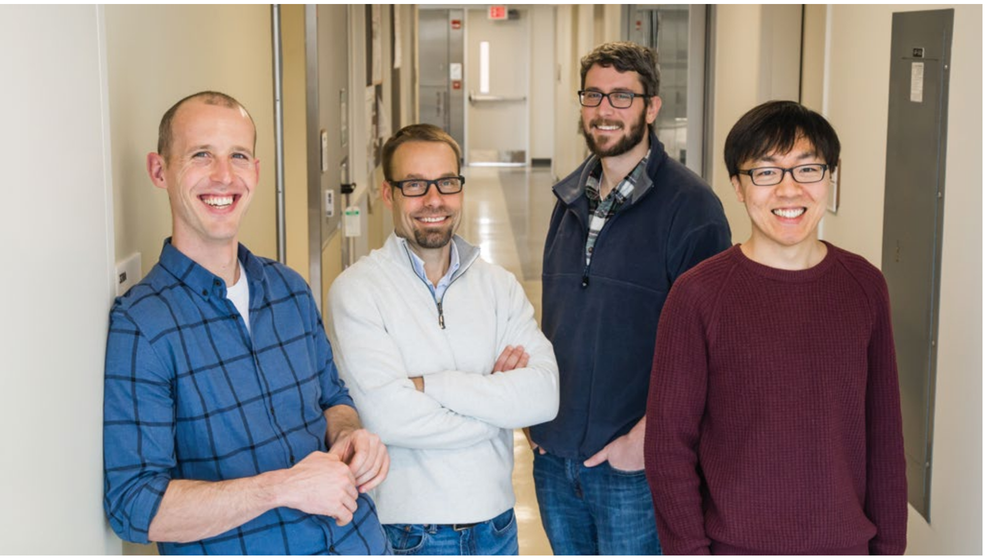
by Adam Hadhazy

Marvels of complexity, cells host many thousands of chemical reactions. Some happen inside specialized compartments, called organelles. Certain organelles, however, lack any membrane to wall themselves off from other cellular matter. These membraneless organelles persist as self-contained structures amidst a cellular sea of water, proteins, nucleic acids, and other molecules.

Princeton engineers have developed a tool — dubbed optoDroplet — that offers unprecedented access to manipulating and understanding the chemistry that allows membraneless organelles to function. The tool, which uses light to manipulate matter inside cells, was developed in part through the combined efforts of Clifford Brangwynne's Soft Living Matter research group, Jared Toettcher's cell biology lab, and Mikko Haataja's computational modeling team.

"This optoDroplet tool is starting to allow us to dissect the rules of physics and chemistry that govern the self-assembly of membraneless organelles," said Brangwynne, an associate professor of chemical and biological engineering. "The basic mechanisms underlying this process are very poorly understood, and if we get a handle on it, there might be a hope for developing interventions and treatments for devastating diseases connected with protein aggregation, such as ALS."

Photo by David Kelly Crow



From left: Jared Toettcher, assistant professor of molecular biology; Mikko Haataja, professor of mechanical and aerospace engineering; Clifford Brangwynne, associate professor of chemical and biological engineering; and Yongdae Shin, postdoctoral fellow, chemical and biological engineering.

Previous research has demonstrated that membraneless organelles assemble within the cell by a process known as a phase transition; an example of familiar phase transitions includes water vapor condensing into dew droplets.

OptoDroplet relies on a technique called optogenetics, involving proteins whose behavior can be altered by exposure to light. (Cells are mostly water and thus essentially transparent.) The researchers showed that they could induce phase transitions and create membraneless organelles by switching on the light-activated proteins. They also could undo the transitions by simply turning the light off. Increasing the light intensity and protein concentrations allowed the researchers to further control the transition. By changing those inputs, they can determine when condensed liquid protein droplets form, as well as solid-like, protein aggregates, possibly linked to diseases.

Based on the experimental work, Haataja's team developed a model to quantitatively describe how the transition occurred in the cells. The model will allow further understanding of the organelle's formation "and provide new insights into the experimental system," said Haataja, a professor of mechanical and aerospace engineering.

"OptoDroplet provides us a level of control we can use to precisely map what we call the phase diagram in living cells," said Brangwynne. "With that, we're beginning to understand how cells use their natural machinery to move through this intracellular phase diagram to assemble different types of organelles." **E**

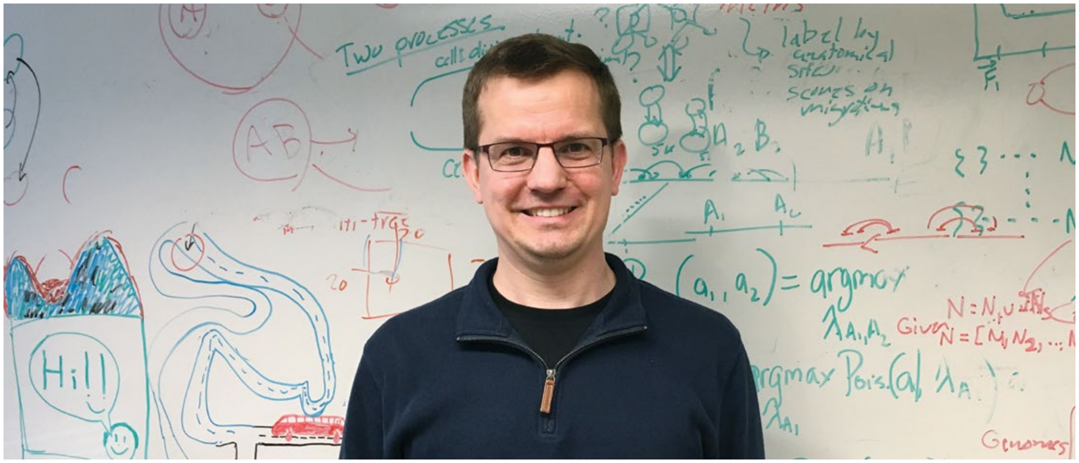


Photo courtesy of Ben Raphael

CANCER BIOLOGY: COMPUTER SCIENTIST IDENTIFIES MUTATIONS THAT MATTER

by Katherine Greenwood

Ben Raphael first applied his computational muscle to the fight against cancer by accident.

As a postdoctoral fellow at the University of California, San Diego, he studied genomes. One day, during a routine research meeting, his adviser mentioned that he had gotten an email from cancer biologists who needed help making sense of their data. He asked the lab group if anyone was interested in participating.

Raphael volunteered, thinking it would be a one-off project. Fifteen years later, he's still studying what drives cancer. "As I got further into cancer genomics there were more and more challenges — both biological and computational — that were intriguing," said Raphael, a professor of computer science.

Somatic mutations — mistakes the cell makes when copying its DNA during cell division — are one key to understanding how cancer grows. "These somatic mutations happen all the time," said Raphael. "Most of them are inconsequential, but a small fraction of them lead to cancer."

That's where the computational tools he creates come in.

Raphael and his team develop algorithms that sift through massive amounts of data generated by DNA sequencing of tumors in search of the cancer-causing mutations.

He compares his work to assembling a jigsaw puzzle: The data from a DNA sequencing machine is like puzzle pieces in a box, and one of the pieces has been altered so it no longer fits in anywhere. But before you can figure out which piece is flawed, you need to put the puzzle together.

The task is enormously complex. Mutations vary in patients with the same type of cancer, and a single tumor can contain several kinds of mutations. Raphael analyzes data from individual tumors to identify the relationships between mutations found in different cells of the same tumor.

He also analyzes data gathered from groups of people with the same type of cancer to identify common mutations that disrupt networks of genes. "By understanding how these mutations lead to cancer, we might find ways to help diagnose and treat it," he said.

Cancer researchers use his powerful algorithms to understand the progression of multiple types of cancer. And he has developed software that physicians eventually could use in clinics to help them make targeted treatment decisions.

"I'm a firm believer that we should use our abilities to try to improve the world," said Raphael. "Our work in cancer genomics is one small way that we're doing this." **E**

Professor of Computer Science Ben Raphael's whiteboard contains calculations about cancer genetics as well as a greeting from his children.

NETWORKS MAP THE COMPLEX PATHS TO CANCER

by John Sullivan

Photo by Frank Wojciechowski

Researchers in the lab of Mona Singh (above) work to find clues to disease in a sea of data about genetic mutations (below).

The word network usually brings to mind computer systems or television broadcasts. In Mona Singh's lab, networks provide a better understanding of the vast amount of data pouring in from research into the human genome.

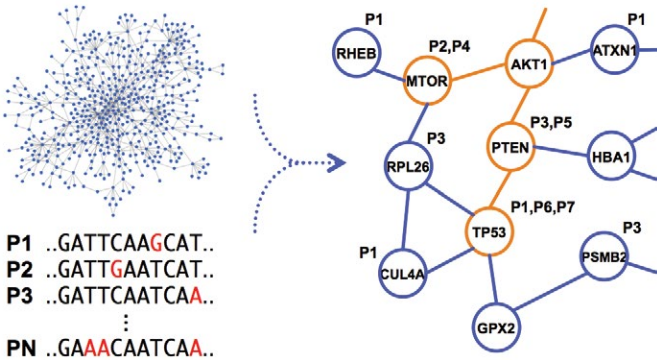


Illustration by Mona Singh

"All modern and future geneticists have to be proficient with statistics and computation," said Singh, a professor of computer science and the Lewis-Sigler Institute for Integrative Genomics. "That is not to say computation replaces any of the genetics done in the lab, not at all, but you are working with larger and larger data sets."

Fundamentally, it is a small step from genetics to computer science. After all, the DNA at the heart of genes is essentially programming for cells and the organ systems they comprise. When cells, or groups of cells, act, they follow sets of instructions encoded in DNA, and much of modern bioengineering is devoted to understanding those instructions. Unfortunately, so many bits of information are delivered to the body's cells at any given time that it becomes phenomenally difficult to say which set of instructions resulted in a specific response.

"For example, if you look at any two individuals, they have different sets of genetic mutations," Singh said. "How do you uncover which genes that are mutated play a role in the development of cancer?"

For most types of cancer, the answer is even more elusive. The disease is believed to result from a series of mutations that occur in sequence, called a pathway, rather than a single set of problematic genes.

"Cancer arises because you have mutations in cells that give them an edge in terms of growth," Singh said. "You get one mutation, and maybe that gives cancer an advantage but not much. Then you get a second mutation and that gives cancer more of an advantage."

In recent work, Singh's lab is narrowing in on sets of mutations that could play a role in a series of developments that lead to some cancers. She said the challenge is discovering which individual variations are important among "this sea of mutations." In one method, Singh's team is developing a network that tracks genetic interactions as a way to identify smaller subnetworks related to genetic mutations. The goal is to identify which sets of mutations are part of pathways to cancer development, and which sets are benign.

"Cancer is a disease of pathways," Singh said. "If we can better understand the pathways, we might be able to disrupt them." **E**

CIRCLING CELLS: MATH AND A CAMERA REVEAL LOGIC BEHIND CELL MOVEMENTS

by Susan DeSantis

Thousands or even millions of cells have to move together to heal a wound or grow new tissue. But how do they coordinate their motion?

Scientists don't have that answer yet, but two Princeton professors with very different expertise have published findings from their work together that provide some insight into a little understood form of collective motion in which large groups of cells form swirling vortices. To get the answers, the researchers combined mathematical modeling with experiments in the laboratory to determine that the cells do not move randomly.

Celeste Nelson, a professor of chemical and biological engineering who runs the experimental laboratory, said that her team focuses on concrete experimentation and wouldn't have thought to do the study if it weren't for Yannis Kevrekidis, the Pomeroy and Betty Perry Smith Professor in Engineering, Emeritus, who specializes in modeling complex systems.

"I think she's way too gracious," said Kevrekidis. But, he added, "It's a wonderful thing for a theorist when mathematical modeling of an experiment can build such a novel and useful result."

In recent work published in Biophysical Journal, the researchers focused on the swirling motion that cells sometimes follow in a small, confined area. The motion, called coherent angular motion, is poorly understood and can involve changes in direction that appear random.

To study this motion, Michael Siedlik, a graduate student in Nelson's lab, and Sriram Manivannan *14, grew cells in an incubator and attached a camera that captured an image every couple of minutes. When these images were analyzed, the students discovered that cell division played an important role in both angular motion and in the switches in direction that occur during the motion. When a cell divides, creating a new one, it creates a disturbance that can affect the motion of neighboring cells.

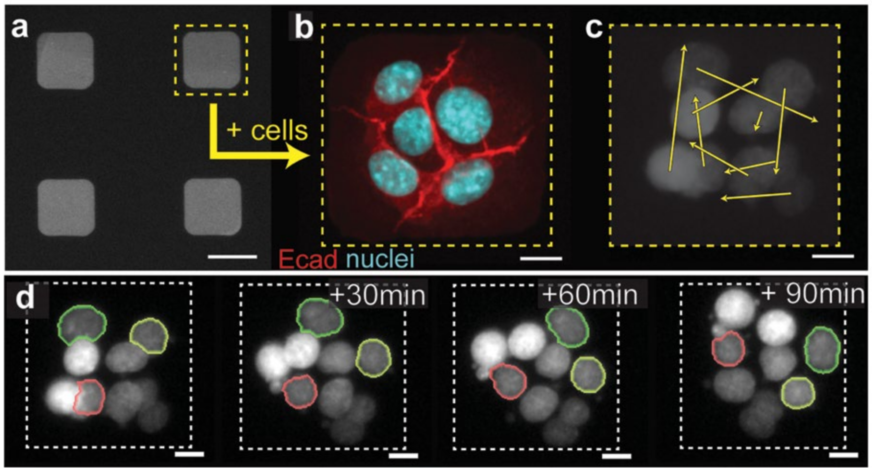
"The ability to move together is something we see in nature such as when a school of fish suddenly rotates in the opposite way," Nelson said. "But what this study found is that adding a new cell completely changes the population and creates this weird, wacky change in rotation."

Kevrekidis said the direction changes in angular motion were previously thought to be random and called the experimental results "remarkable."

The researchers said they would like to continue their work on collective angular motion. They are particularly interested in whether the motion creates a feedback loop in which cellular division creates collective angular motion and collective angular motion also influences cellular division.

"Our findings highlight the importance of dividing cells within tissues that exhibit complex behavior," they wrote in the study. "Given that coherent motion is ubiquitous in multiparticle systems, from cell biology to ecology to granular mechanics, it will be interesting to determine whether the effects of introducing new particles are broadly generalizable to the internal dynamics of diverse systems." **E**

Image courtesy of the researchers



Breast tissue cells exhibit circular motion. Princeton engineers studied the phenomenon by printing micrometer-sized islands of connective tissue onto a silicone surface and seeding cells into these regions. The cells rotated over a period of 90 minutes.

RECENT FACULTY AWARDS, PROMOTIONS, AND HONORS

Pablo Debenedetti

Peter Jaffe

Prateek Mittal

Photos by Frank Wojciechowski unless otherwise indicated

CHEMICAL AND BIOLOGICAL ENGINEERING

José Avalos
Pew Scholar in the Biomedical Sciences
Howard B. Wentz, Jr. Junior Faculty Award

Mark Brynildsen
E-Council/GEC Excellence in Teaching Award

Pablo Debenedetti
2016 Guggenheim Medal, Institution for Chemical Engineers

Yannis Kevrekidis
Elected to the American Academy of Arts and Sciences

Celeste Nelson
Finalist, Blavatnik National Awards for Young Scientists
College of Fellows, American Institute for Medical and Biological Engineering

Rodney Priestley
2017 Owens Corning Early Career Award, Materials Engineering & Sciences Division of the American Institute of Chemical Engineers

CIVIL AND ENVIRONMENTAL ENGINEERING

Maria Garlock
Fellow, Structural Engineering Institute of the American Society of Civil Engineers

Peter Jaffe
William L. Knapp '47 Professor of Civil Engineering

Ning Lin *10
CAREER Award, National Science Foundation

Ning Lin

Catherine Peters
Chair, Department of Civil and Environmental Engineering

Claire White
Howard B. Wentz, Jr. Junior Faculty Award

Eric Wood
2016 Fellow, American Association for the Advancement of Science
Robert E. Horton Medal, American Geophysical Union

COMPUTER SCIENCE

Nick Feamster
Fellow, Association of Computing Machinery

Margaret Martonosi
ACM SIGMOBILE Test of Time Paper Award (for research group)

Arvind Narayanan
CAREER Award, National Science Foundation
E. Lawrence Keys, Jr./Emerson Electric Company Award
E-Council/GEC Excellence in Teaching Award

Jennifer Rexford '91
2017 Harrold and Notkin Research and Graduate Mentoring Award, National Center for Women and Information Technology

ELECTRICAL ENGINEERING

Nathalie de Leon
Young Investigator Program Award, Office of Naval Research
Sloan Foundation Fellowship

Nathalie de Leon

Jason Fleischer
Member, 2018-19 Defense Science Study Group

Andrew Houck '00
E-Council/GEC Excellence in Teaching Award

Sharad Malik
A. Richard Newton Technical Impact Award in Electronic Design Automation

Prateek Mittal
Google Faculty Research Award
E. Lawrence Keys, Jr./Emerson Electric Company Award

H. Vincent Poor *77
2017 Alexander Graham Bell Medal, IEEE
D.Sc. honoris causa, Syracuse University
Honorary Member, National Academy of Sciences of Korea
Foreign Member, National Academy of Engineering of Korea

Photo by David Kelly Crow

H. Vincent Poor

Fellow, International Scientific Radio Union (URSI)
Honorary professorships at Peking University, Tsinghua University, and University of California-Berkeley

Kaushik Sengupta
Young Investigator Program Award, Office of Naval Research

Kaushik Sengupta

MECHANICAL AND AEROSPACE ENGINEERING

Craig Arnold
Fellow, The Optical Society
E-Council/GEC Excellence in Teaching Award

Emily Carter
2017 Irving Langmuir Prize in Chemical Physics, American Physical Society

Marcus Hultmark **11*
CAREER Award, National Science Foundation
Nobuhide Kasagi Award, Tenth International Symposium on Turbulence and Shear Flow Phenomena

Naomi Ehrich Leonard '85
2017 Hendrik W. Bode Lecture Prize, IEEE Control Systems Society

Julia Mikhailova
Alfred Rheinstein Faculty Award

Clancy Rowley '95
Head, Rockefeller College
E-Council/GEC Excellence in Teaching Award

Alexander Smits
90th Anniversary Medal, Fluids Engineering Division, American Society of Mechanical Engineers

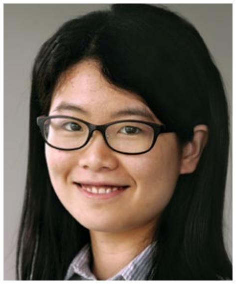
Clancy Rowley

OPERATIONS RESEARCH AND FINANCIAL ENGINEERING

Amir Ali Ahmadi
Sloan Foundation Fellowship

Han Liu
Sloan Foundation Fellowship

Mengdi Wang
CAREER Award, National Science Foundation



Mengdi Wang

Photos by Frank Wojciechowski unless otherwise indicated

ENGINEERING FACULTY MEMBERS TAKE ON LEADERSHIP ROLES

Sanjeev Kulkarni, professor of electrical engineering, became Princeton University's dean of the faculty effective July 1. Kulkarni, who was previously dean of the Graduate School, succeeded Deborah Prentice, who is now provost.

President Christopher L. Eisgruber said that Kulkarni's "interdisciplinary research, his wide-ranging service to the University, and his leadership of the Graduate School have given him a deep appreciation for the values shared throughout our University and the scholarly practices that distinguish our departments."

Kulkarni previously served as associate dean of engineering for academic affairs, director of the Keller Center for Innovation in Engineering Education, and head of Butler College. His research interests include statistical pattern recognition, machine learning, nonparametric estimation, information theory, wireless networks, signal/image/video processing, and econometrics and finance.

Margaret R. Martonosi, the Hugh Trumbull Adams '35 Professor of Computer Science, became director of the Keller Center July 1. The center supports innovative courses, co-curricular activities, and internships that cross disciplines, connect technology and society, and foster entrepreneurship and design thinking.

Photo by David Kelly Crow

Martonosi, whose research focuses on computer architecture and mobile computing, succeeds Mung Chiang, who became dean of engineering at Purdue University.

"Margaret brings a multitude of experiences to this role that will strengthen and expand the impact of the center's work," said Emily Carter, dean of engineering, "including expertise in creating and assessing education and mentoring initiatives and a global perspective catalyzed by her recent stint as a Jefferson Science Fellow working on technology policy at the State Department. She also cares deeply about educating and mentoring the next generation."

Catherine Peters, professor of civil and environmental engineering, has been appointed chair of her department effective July 1.

"This is a time of enormous importance for the field of civil and environmental engineering, given the vast challenges the world faces in ensuring human safety and health and in protecting the environment," Peters said. "As chair, I will work with faculty to advance academic and scholarly innovations to grow and redirect the department in light of these grand challenges."

Peters' research focuses on geochemistry, including the intersection of water quality and energy technologies such as carbon sequestration, geothermal energy, and hydrofracking. She previously served as associate dean of engineering, acting department chair, president of the Association of Environmental Engineering and Science Professors, and a member of the U.S. EPA Science Advisory Board.

Photos by Frank Wojciechowski
unless otherwise indicated

TEACHERS' PASSION AND MENTORING HELP SET LIFE TRAJECTORIES

Four engineering professors were recognized for outstanding teaching in the 2017 graduation ceremonies.


Photo by Dani Dillena

Amir Ahmadi, an assistant professor of operations research and financial engineering, received the Phi Beta Kappa teaching award. In a citation for the award, Graham Turk '17 praised Ahmadi's accessibility, his interest in his students' ability to learn and his "incredible capacity for empathy." Ahmadi "went above and beyond to help us understand the concepts" and "possesses an uncanny ability to explain complex proofs in a way that helps his students develop their own critical thinking arsenals," Turk said.

Michael Celia *83, the Theodora Shelton Pitney Professor of Environmental Studies and professor of civil and environmental engineering, received the engineering school's Distinguished Teaching Award. In presenting the award at Class Day, Antoine Kahn, the vice dean of engineering, said that Celia has been an outstanding teacher and an exceptional mentor to graduate students, post-docs, and junior faculty. Kahn said undergraduates praised Celia as a teacher, calling him an "incredible lecturer" who made mathematical modeling cool. "When I graduated from Princeton, I had one ambition; I wanted to be like Mike," one student said. One former postdoctoral researcher said Celia "strongly influenced my development as a teacher when he served as my mentor."


Photo by David Kelly Crow

Howard Stone, the Donald R. Dixon '69 and Elizabeth W. Dixon Professor of Mechanical and Aerospace Engineering and department chair, received the President's Award for Distinguished Teaching at the Commencement ceremony. Stone is known for his ability to explain difficult mathematical concepts and for his commitment to mentoring. A colleague described Stone as "a kind and caring educator who excels in bringing out the best in students, researchers, staff, and colleagues." A graduate student said Stone's passion for the subject matter, including a love for differential equations, "set the tone for the semester." An undergraduate said Stone's lectures "were always incredibly clear, well-structured, and engaging. What made [them] so effective was their emphasis on using systematic mathematical reasoning over rote memorization."


Photo by Frank Wojciechowski

Sankaran Sundaresan, the Norman John Sollenberger Professor in Engineering and professor of chemical and biological engineering, received the Graduate Mentoring Award during the Graduate School's Hooding ceremony. An alumnus praised Sundaresan's help in preparing for a conference. "He made sure that I gave the practice talk a month before the conference. [He] then patiently and skillfully worked with me over the next few weeks to revise and improve the talk." One former student, thankful for how Sundaresan connected him to multiple job opportunities, said, "It is humbling to think that all I have today in life and my trajectory in the corporate and research ladder is due to this one great man."


Photo by Denise Applewhite

SENIOR THESIS DEEPENS UNDERSTANDING OF AN ARCHITECTURAL ICON IN CUBA

Builder José Mosquera's masterwork languishes in a wooded area outside Havana, Cuba, going slowly to ruin and being colonized by trees and vines. But when Princeton senior Isabella Douglas and a team of students met Mosquera on the grounds of Cuba's National School of Ballet last November, he gave them a rare gift.

An album of 50-year-old photographs — up to 20 pages of images taken at various stages — shows the school being built, including pictures of the very construction technique Douglas had hoped to examine when she visited Cuba. The photographs exist nowhere else in the world. They provide not only a record of how the famed ballet school went up, but help usher in a significant shift in understanding of the use of thin-tile vaulting, the subject of Douglas' senior thesis, "Cuba's National School of Ballet: Redefining a Structural Icon."

"When we finished, he was really emotional," said Douglas, a civil and environmental engineering major who made a digital archive of the photos. "He said seeing students [young engineers] come in and fall in love with the structure as he loved it was really the best gift he could have gotten."

Douglas, who comes from an academic family in Bloomington, Indiana — both parents are professors — considers herself "very analytical." But she also loves old buildings, dating from childhood construction and carpentry projects and reinforced by a visit to a warehouse in Galveston, Texas, damaged by the great hurricane of 1900. These interests blended seamlessly at Princeton, where Douglas also earned a certificate in architecture and engineering.

As part of her studies, Douglas traveled to Cuba last fall with the course "A Social and Multi-Dimensional Exploration of Structures." Branko Glišić, an associate professor of civil and environmental engineering who co-organized the trip with Maria Garlock, a professor of civil and environmental engi-

The arched structures of Cuba's National School of Ballet near Havana became the focus of the senior thesis of Isabella Douglas, who visited during a class trip last fall and graduated in June.

neering, said the ballet school, known for its graceful tiled dome, is one of the country's most beautiful structures. The building also poses several intriguing engineering questions, particularly about the dome's construction.

Douglas, who goes by the nickname Belle, had already completed "outstanding" independent research on the construction of London's Crystal Palace and seemed the ideal person to answer some of those questions, Glišić said. So he and Garlock asked Douglas to conduct a structural analysis of the building during the trip.

"Knowing Belle, her graduate-level talents, and her enthusiasm for historic structures, we invited her to work on the project," said Garlock, who is also director of the Program in Architecture and Engineering.

The ballet school's dome has long been considered an example of thin-tile vaulting, also called "Catalan" vaulting, a construction technique dating to Roman times. Catalan vaults are constructed of small tiles and quick-setting mortar. The builders add structural strength by layering the tiles on top of each other as they fill in the dome — spots that need more strength have thicker layers. The technique allows builders to create graceful arches and domes without building wooden frames to brace them during construction. But the method is demanding and requires carefully estimating the thickness of different areas.

Garlock and Glišić wanted to know how this was done at the ballet school, and Douglas, intrigued, set about finding out.

After receiving permission to inspect the school last November, Douglas and the Princeton team took numerous photographs and measurements of the building's main dome — including details such as the numbers of tiles in its edge pieces.

While they were walking on the school's roof, Douglas and the team found cracks through which they saw reinforcing steel bars, known as "rebar," the mesh of steel wires used in reinforced concrete. The discovery showed that the building was not wholly built with thin-tile vaulting construction, but was fortified at critical junctures with concrete.

"None of us from Princeton believed we had found rebar at first," Douglas said.

In her thesis, Douglas explained that the dome is supported by ribs of reinforced concrete, which are covered with tile. The superstructure sits upon adobe brick walls.

"It is actually not a Catalan vault after all," Glišić said.

Glišić and Garlock said Douglas' thesis is a significant contribution to the understanding of the structure, and they plan to submit it for publication in a scholarly journal. Douglas, now in graduate school at Stanford University, hopes her findings will aid in work to preserve the ballet school.

The fact that the building can no longer be considered an example of Catalan vaulting does not diminish its significance, Douglas said. The builders worked with materials and skills available at the time and used them exactly as they should.

"We didn't ever want to lessen the structure by what we found," she said. "We wanted to give it a more complete story." **–Wendy Plump**

Photo by David Kelly Crow

Students and faculty from the Department of Civil and Environmental Engineering gathered for an opening reception for an exhibit of models students made after a class trip to Cuba, including Douglas' model of the ballet school domes. From left: Branko Glišić, associate professor; Douglas; Rebecca Napolitano, graduate student and teaching assistant for the course; and Maria Garlock, professor.

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

During their four years at Princeton, members of the Class of 2017 helped develop new ways to deliver antimalarial drugs, created software that measures the stability of masonry arches, and even built an app that uses a smartphone to measure the speed of a fastball. The 308 engineering students in the class moved on to new challenges at top graduate schools including MIT, Stanford, and Caltech; with employers including Merck, Google, and Lockheed Martin; and in professional sports and the military. At Class Day ceremonies June 5, the School of Engineering and Applied Science presented the following awards.

Photos by David Kelly Crow

Above, Dean Emily Carter (second from left) congratulates Siddhartha Jayanti, Brendan Hung, and Demi Fang on winning the Calvin Dodd MacCracken Senior Thesis/Project Award. Their respective theses involved creating an investment system to help people escape poverty and create wealth in the developing world, novel approaches to a classic problem in algorithm design called a disjoint set union, and the development of a tool to assess the stability of masonry arches and vaults.
Below, Alain Kornhauser *71, professor of operations research and financial engineering (center), congratulates Vladimir Feinberg and Lydia Liu, both of whom were among his freshman advisees four years ago.

J. Rich Steers Award
Rachel Herrera
Mechanical and Aerospace Engineering
Corrie Kavanaugh
Civil and Environmental Engineering

Tau Beta Pi Prize
Maxim Zaslavsky
Computer Science
Tyler Hoffman
Operations Research and Financial Engineering

Joseph Clifton Elgin Prize
Ryan Miller
Operations Research and Financial Engineering
Natasha Turkmani
Civil and Environmental Engineering

George J. Mueller Award
Ellen Dobrijević
Chemical and Biological Engineering
Chad Powers
Mechanical and Aerospace Engineering

Calvin Dodd MacCracken Senior Thesis/Project Award
Brendan Hung
Operations Research and Financial Engineering
Siddhartha Jayanti
Computer Science
Demi Fang
Civil and Environmental Engineering

Lore Von Jaskowsky Memorial Prize
Suyang Kevin Wang
Electrical Engineering
Isabella Douglas
Civil and Environmental Engineering

James Hayes-Edgar Palmer Prize in Engineering
Vladimir Feinberg
Computer Science
Lydia Liu
Operations Research and Financial Engineering

GRADUATE STUDENTS RECOGNIZED FOR EXCELLENCE IN TEACHING

Last spring, three engineers were among 10 graduate students who received the Graduate School's annual Teaching Awards in recognition of their outstanding abilities.

Jonathan MacArt of mechanical and aerospace engineering served as an assistant in instruction (AI) for MAE 427, "Energy Conservation and the Environment: Transportation Applications" and MAE 335, "Fluid Dynamics." According to Assistant Professor of Mechanical and Aerospace Engineering Michael Mueller, "Jon showed a tremendous ability to be able to explain concepts to students in a variety of ways that helped them better understand the course material. He provided handwritten notes on his precepts that were universally praised by the students for their clarity." One student said: "He did not give us the answers to problem set questions during office hours. Instead, he challenged us to work through problems ourselves. His answers to our questions were never yes/no, but 'what do you think?' and 'why?', which encouraged us to really dig deep into the equations and theorems."

Rebecca Napolitano of civil and environmental engineering served as an AI for three courses: CEE 361/MAE 325/MSE 331, "Matrix Structural Analysis and Introduction to Finite-Element Methods"; CEE 102, "Engineering in the Modern World"; and CEE/LAS 463, "A Social and Multi-Dimensional Exploration of Structures." Associate Professor of Civil and Environmental Engineering Branko Glišić described Napolitano's magic in an 8:30 a.m. precept: "She managed to create an incredibly awake and positive learning environment where students from different departments will speak the same language, and eagerly and intensively collaborate on solving the problems. Every success was loudly cheered by students, and I could witness widespread genuine joy that students felt when learning." According to one student, "Becca did not feed us answers, but rather guided us to think about problems and different ways of solving them, giving us transferable skills."

Ziwei Zhu of operations research and financial engineering was independently nominated by the faculty instructors in both courses in which he assisted as head AI: ORF 350, "Analysis of Big Data," and ORF 245, "Fundamentals of Statistics." Jianqing Fan, the Frederick L. Moore, Class of 1918, Professor of Finance, commented on the complexity of teaching a first course in statistics to students with widely varying backgrounds. He said that Zhu "took the leading role in the development and teaching of this challenging course and made significant and profound contributions throughout the semester. He is passionate about bringing interesting and concrete problems or examples to our undergraduate students and cultivating their interest in statistics." As one student described it, "Ziwei is knowledgeable, approachable, and clear. His teaching was instrumental in helping me succeed in the course." **–Staff**

Last spring, electrical engineering professor Sanjeev Kulkarni (center), former dean of the Graduate School and now dean of the faculty, honored graduate students for excellence in teaching and service. Among the recipients were engineering students Ziwei Zhu (fourth from left), Jonathan MacArt (third from right), and Rebecca Napolitano (not shown).

Photo by Tori Repp/Fotobuddy

GRADUATE STUDENT RESEARCH TARGETS FUNDAMENTAL PROBLEMS WITH BROAD IMPACT

Their academic backgrounds and tools are diverse, but the projects Princeton engineering graduate students pursue have a common thread: They combine research into fundamental questions with an end goal of solving important societal problems. The sample of projects featured here range from the underlying causes of cancer metastasis to mathematical techniques for optimizing complex decision-making processes with implications for electricity grids, financial markets, and the operation of blood banks.

ALIŞYA ANLAŞ

CHEMICAL AND BIOLOGICAL ENGINEERING

Hometown:
Istanbul, Turkey

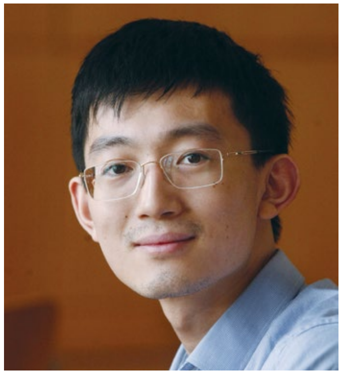
Ninety percent of cancer-related deaths are due to the spread of cancer cells throughout the body in a process called metastasis. A major challenge facing medicine is the tendency of disseminated cancer cells to go "dormant" and evade clinical detection. Anlaş' research seeks to understand how interactions between a tumor and its environment affect cancer-cell dormancy. Specifically, she uses a 2-D engineered tissue model to mimic the stiffness of common sites for breast cancer metastasis as a way to explore how tissue stiffness affects cancer cell dormancy and growth. Anlaş hopes to elucidate some of the pathways that regulate the switch from dormancy to proliferation to understand how the growth of cancer cells can be kept under control.

HIBA ABDEL-JABER

CIVIL AND ENVIRONMENTAL ENGINEERING

Hometown:
Dubai, United Arab Emirates

The goal of Abdel-Jaber's research is to create objective, quantitative methods for assessment of the structural performance and condition of civil structures and infrastructure. Her approach is to use sensors that measure key structural parameters rather than rely on visual inspections. By combining the theory of structures, material modeling, and long-term measurements from fiber-optic sensors embedded in Princeton's Streicker Bridge, Abdel-Jaber aims to create methods that can be used on a wide range of similar structures. Abdel-Jaber's ultimate aim is to create methods that allow for informed decisions that improve structures' safety, sustainability, and resilience.



TENGYU MA

COMPUTER SCIENCE

Hometown:
Changchun, China

Ma's career mission is to contribute in fundamental ways to the advancement of machine learning and other fields of artificial intelligence. Many modern machine learning techniques use artificial neural networks, aspects of which are poorly understood. While these methods enjoy empirical success, the discovery of the principles behind them will sustain and boost the progress of the field in the long term. Ma's research contributes to the theoretical developments of many topics in machine learning and related algorithms including non-convex optimization, representation learning, deep learning, and convex relaxation.

YUSHAN LIU

ELECTRICAL ENGINEERING

Hometown:
Yangzhou, Jiangsu Province, China

Liu focuses on data privacy, network security, and machine learning. Social network data sets have been used to create applications such as recommendation systems. However, there is immense tension between the utility of systems that rely on social network data and users' privacy concerns. Liu works on technologies that enhance security and privacy without compromising other desirable system properties. Another of Liu's projects involves the Tor system, a popular anonymous communication network. Liu is working to minimize exploitation of Tor by botnets without degrading privacy for other Tor users.

JESSE AULT

MECHANICAL AND AEROSPACE ENGINEERING

Hometown:
La Porte, Indiana

Ault's research lies at the intersection of applied mathematics, scientific computing, and the dynamics of complex fluids. He recently characterized a fluid dynamics phenomenon known as vortex breakdown in bending and branching flows and used it to manipulate particles and biomaterials in microfluidic devices. Ault also uses a particle transport phenomenon known as diffusiophoresis to enhance directed particle motions into otherwise difficult to reach geometries. He recently demonstrated a fast, low-cost technique to measure the surface charge of particles based on these ideas. This work also has potential applications in improving the efficiency of cosmetics and pharmaceuticals, as well as in oil and gas recovery in hydraulic fracking.

Photos by Frank Wojciechowski

RAYMOND PERKINS

OPERATIONS RESEARCH AND FINANCIAL ENGINEERING

Hometown:
Columbia, South Carolina

Perkins' research focuses on stochastic optimization and machine learning, formalizing a class of commonly used heuristics called parametric cost function approximations. Unlike many alternative methods, this strategy is computationally inexpensive, adaptive, and able to manage problem uncertainty. Perkins has developed a gradient-based stochastic search strategy to optimize these models and is applying this strategy to manage smart electricity grids. His research is applicable to a wide range of problems such as resource management, scheduling, health care, finance, and energy. In an upcoming project, he intends to use these algorithms to efficiently manage blood banks.

ALUMNI APPOINTED TO LEADERSHIP POSITIONS

Yan Huo, managing partner and chief investment officer of Capula Investment Management, was elected to the Board of Trustees of Princeton University. He earned his Ph.D. in electrical engineering from Princeton in 1994.


Andrew Krivoshik

Andrew Krivoshik '90 has been promoted to vice president of medical science-oncology at Astellas Pharma Global Development. Krivoshik received his undergraduate degree in electrical engineering from Princeton and a medical degree from the University of Illinois College of Medicine at Urbana-Champaign. Krivoshik is licensed as both a physician and an engineer.


David Munson Jr.

David Munson Jr. *79 became the 10th president of the Rochester Institute of Technology on July 1. Munson previously served two terms as dean of engineering at the University of Michigan where he also was a professor of electrical engineering and computer science. Munson earned a Ph.D. in electrical engineering and computer science from Princeton and a B.S. in electrical engineering from the University of Delaware.


John Ochsendorf

John Ochsendorf *98 became director of the American Academy in Rome on July 1. Following his three-year appointment, Ochsendorf plans to return to his professorships at the Massachusetts Institute of Technology where he holds dual appointments in architecture and civil and environmental engineering. Ochsendorf holds a B.Sc. from Cornell University, an MSE in civil engineering from Princeton, and a Ph.D. from Cambridge University.

Ketan Patel '92 has been named executive vice president, secretary, and general counsel at Forest City Realty Trust, a national real estate company. Patel moves from FirstEnergy Corp. where he was vice president, corporate secretary, and chief ethics officer. He received his BSE in electrical engineering from Princeton and his J.D. from the University of Michigan Law School.


Eric Roegner

Eric Roegner '91 was appointed president of Arconic Global Rolled Products in addition to his position as president of Arconic Defense. Roegner has been with Arconic, a manufacturer of lightweight metal products, since 2006, when it was Alcoa Inc. He received his BSE in mechanical and aerospace engineering from Princeton and his MBA from Case Western Reserve University.


Lori Setton

Lori Setton '84 has been named the Lucy and Stanley Lopata Distinguished Professor of Biomedical Engineering by Washington University in St. Louis. A graduate of Princeton's Department of Mechanical and Aerospace Engineering, Setton serves on the department's advisory council. She received her Ph.D. in mechanical engineering from Columbia University.

Carl Theobald '92 was appointed president and chief executive officer of RichRelevance, which provides customers a personalized shopping experience featuring over 200 brands. Theobald, who has served as CEO of FollowAnalytics and of Avangate, began at Oracle, after receiving a master's degree in engineering from Stanford University and a BSE in electrical engineering from Princeton.

All photos courtesy of subjects

ALUMNI RECOGNIZED FOR ACHIEVEMENTS


Frances Arnold

Frances Arnold '79 was honored with the 2017 Raymond and Beverly Sackler Prize in Convergence by the National Academy of Sciences for her accomplishments in directed evolution, which has been applied to enzymes for creating biofuels, pharma–ceuticals, and industrial products. Arnold received her BSE in mechanical and aerospace engineering from Princeton and her Ph.D. in chemical engineering from the University of California, Berkeley.

Two Princeton engineering graduates were among new fellows recognized by the Association for Computing Machinery in June. **Dan Boneh** *96, who received his Ph.D. in computer science, is a professor of computer science and electrical engineering at Stanford University. **Monika Rauch Henzinger** *93, who earned a Ph.D. in computer science, is a professor of computer science at the University of Vienna, Austria.


Monika Rauch Henzinger

Modern Healthcare magazine included **Laura Forese** '83 in its Top 25 COOs in Healthcare 2017. Forese is the executive vice president and COO of New York-Presbyterian and an associate clinical professor of orthopedic surgery at Columbia University. Forese is also the chairperson of the National Institutes of Health Clinical Center Hospital Board and a trustee of Princeton University. She received her bachelor's in civil engineering from Princeton and her M.D. and MPH from Columbia.

Conor Madigan '00, chief operating officer and president of Kateeva, was named Inventor of the Year for 2016 by the Silicon Valley Intellectual Property Law Association. With over 100 patents under his name, Madigan was recognized for developing equipment to mass produce organic light-emitting diodes, which are used in flat-panel and flexible displays. Madigan received his BSE in electrical engineering from Princeton and his Ph.D. from MIT.

Ted Hall '70 was named the 2017 Napa Valley Grower of the Year for contributions to the Napa Valley wine industry and community. As president and CEO of Long Meadow Ranch since 1989, Hall was recognized for following a motto of "excellence through responsible farming," resulting in agricultural preservation, sustainable practices, and dedicated community focus. Hall received his BSE in electrical engineering from Princeton and his MBA from the Stanford University School of Business.

Diane Souvaine *86, a professor of computer science and senior adviser to the provost at Tufts University, was elected a fellow of the American Association for the Advancement of Science. Souvaine, who also holds an appointment in mathematics, was recognized for her "contributions to the field of computational geometry and for exemplary service on behalf of the computing community." She holds a B.A. in mathematics and English from Harvard, an AMSL in mathematical sciences from Dartmouth College, and a Ph.D. in computer science from Princeton.

Jackie Yi-Ru Ying *91, executive director of the Institute of Bioengineering and Nanotechnology in Singapore, received the 2017 Abdeali Tayebali Lifetime Achievement Award. The award recognizes her contributions to society through scientific research. Ying received her Ph.D. in chemical engineering from Princeton.


Jackie Ying

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