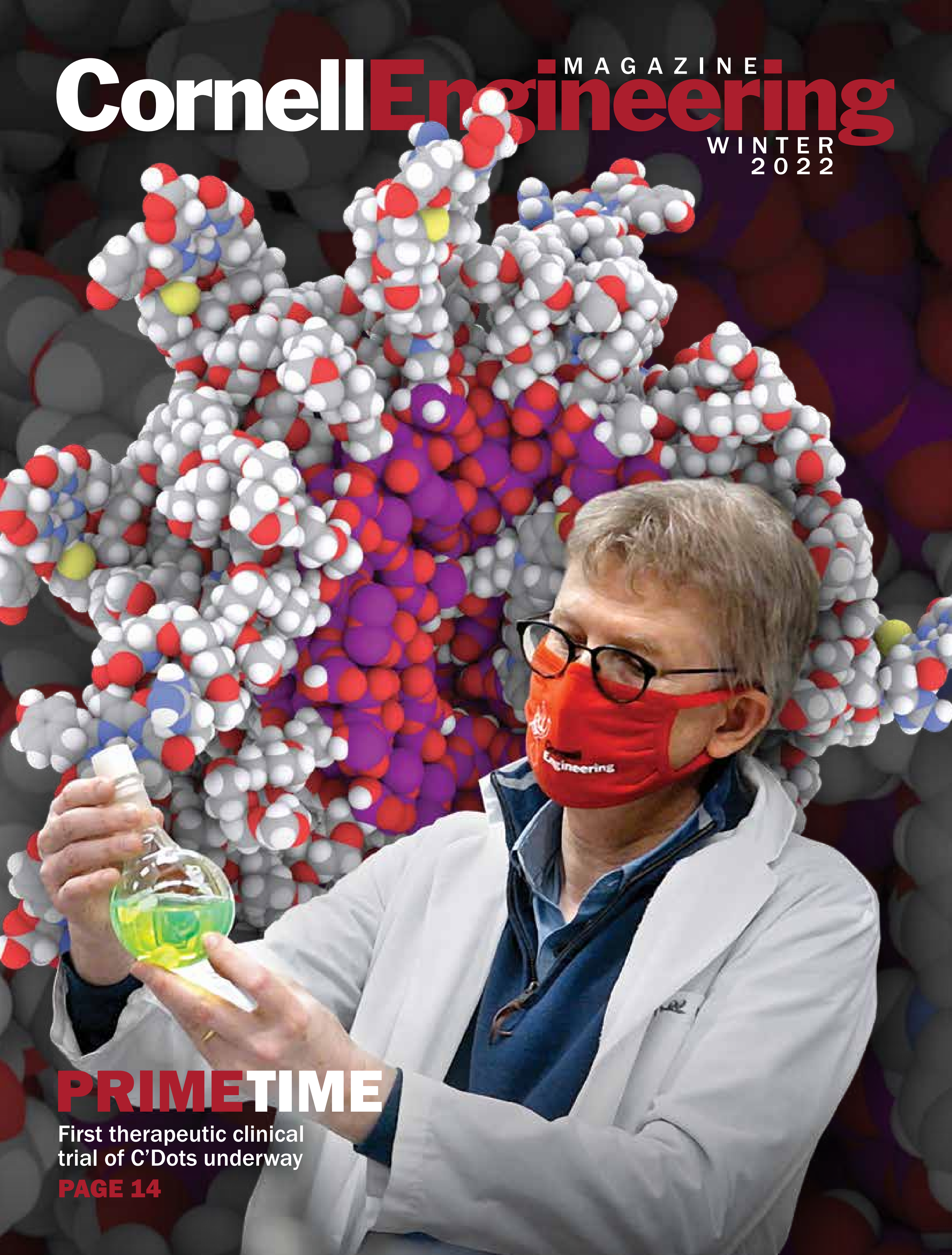
Cornell Engineering MAGAZINE

WINTER 2022



PRIMETIME

First therapeutic clinical trial of C'Dots underway

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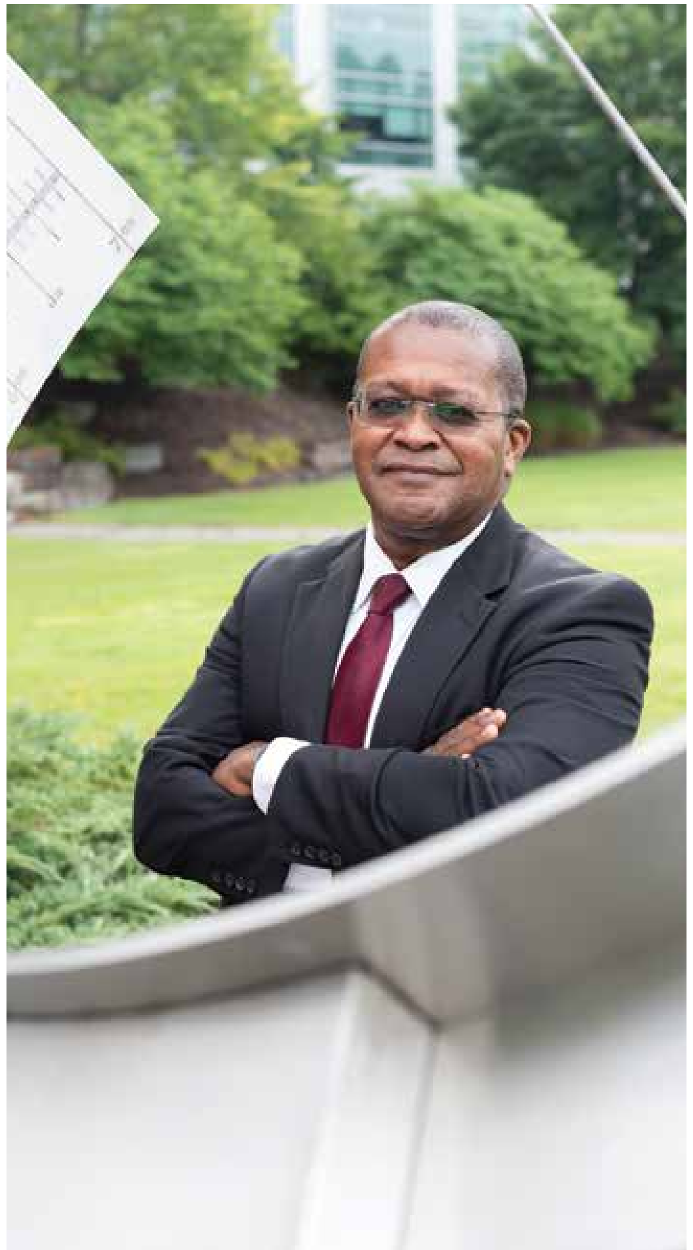

MESSAGE FROM THE DEAN

LYNDEN A. ARCHER

Our world is more connected now than at any time in history. Technology, ideas, information and cultures are colliding in new ways and at an unprecedented scale and complexity.

How do we educate students who are able to thrive in this environment? What investments are needed to innovate impactful solutions to the most difficult problems of our time, such as those relating to climate and energy systems, precision medicine and human health, and inequitable access to STEM education? How do we go about un-siloing engineering disciplines to catalyze convergent approaches that transcend disciplinary boundaries and contribute to positive change?

There is more at stake now in finding actionable answers to these questions than ever before.

Cornell Engineering is uniquely positioned to develop and implement meaningful solutions that make a sustained impact. Our 150-year-old college's well-earned reputation for rigor and excellence in teaching and research, Cornell's deeply ingrained culture of collaborating across disciplines, and our demonstrated commitment to diversity and inclusion provide pillars upon which we'll build new paradigms for engineering education, research, and technology translation.

This is our time!

To seize the moment, we've developed a strategic plan termed Cornell Engineering 2030. I invite you to read more about it on our website.

The plan specifically calls for focused investments in people, programs, and infrastructure that will position Cornell Engineering for national and international leadership.

In education, we will invest in faculty and staff committed to innovating in the classroom to enhance learning. We will integrate leadership, ethics, and professional development education throughout our undergraduate and professional master's degree programs. We will develop distance learning options that improve flexibility for traditional residential students, as well as to increase the college's reach to non-traditional students where they work and live.

In research, we will create mechanisms for rewarding, promoting, and celebrating excellence. To un-silo engineering, we will prioritize recruitment of faculty leaders whose scholarly work lies at the intersection of traditional disciplinary domains in the college. We will also invest in One Cornell Engineering initiatives that build new bridges to Cornell Tech and Weill Cornell Medicine. Finally, we will modernize the college's aging infrastructure — building by building — to create state-of-the art facilities that support new exploration in old and new domains of scholarship.

Our goals are ambitious, and I look forward to keeping you updated as we approach them.

Lynden A. Archer
Joseph Silbert Dean of Engineering
James A. Friend Family Distinguished
Professor of Engineering

CornellEngineering

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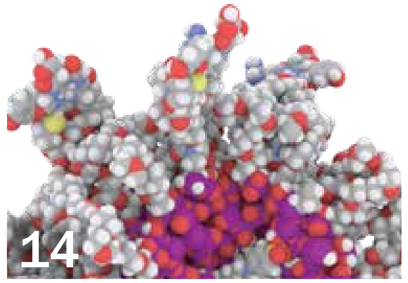

DEPARTMENTS

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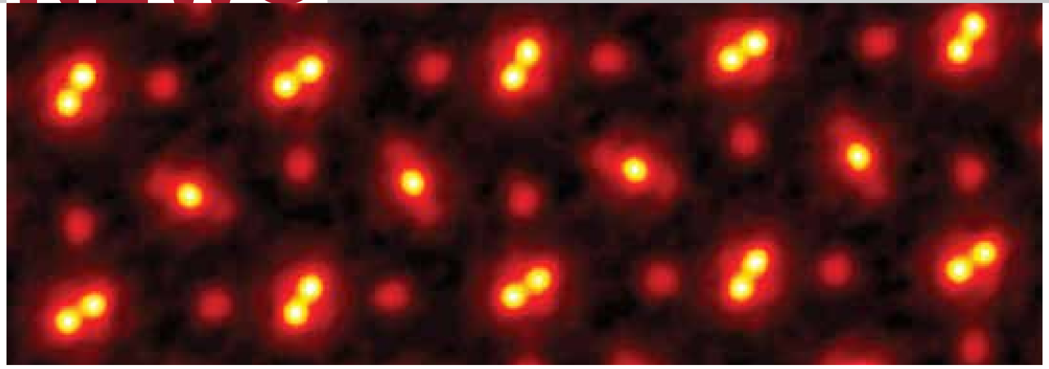


This image shows an electron ptychographic reconstruction of a praseodymium orthoscandate (PrScO3) crystal, zoomed in 100 million times.

CORNELL RESEARCHERS SEE ATOMS AT RECORD RESOLUTION

In 2018, Cornell researchers built a high-powered detector that, in combination with an algorithm-driven process called ptychography, set a world record by tripling the resolution of a state-of-the-art electron microscope.

As successful as it was, that approach had a weakness. It only worked with ultrathin samples that were a few atoms thick. Anything thicker would cause the electrons to scatter in ways that could not be disentangled.

Now a team, again led by David Muller, the Samuel B. Eckert Professor of Engineering, has bested its own record by a factor of two with an electron microscope pixel array detector (EMPAD) that incorporates even more sophisticated 3D reconstruction algorithms.

The resolution is so fine-tuned, the only blurring that remains is the thermal jiggling of the atoms themselves.

"This doesn't just set a new record," Muller said. "It's reached a regime which is effectively going to be an ultimate limit for resolution. We basically can now figure out where the atoms are in a very easy way. This opens up a whole lot of new measurement possibilities of things we've wanted to do for a very long time. It also solves a long-standing problem – undoing the multiple scattering of the beam in the sample, which Hans Bethe laid out in 1928 – that has blocked us from doing this in the past."

Ptychography works by scanning overlapping scattering patterns from a material sample and looking for changes in the overlapping region.

"We're chasing speckle patterns that look a lot like those laser-pointer patterns that cats are equally fascinated by," Muller said. "By seeing how the pattern changes, we are able to compute the shape of the object that caused the pattern."

The detector is slightly defocused, blurring the beam, in order to capture the widest range of data possible. This data is then reconstructed via complex algorithms, resulting in an ultraprecise image with picometer (one-trillionth of a meter) precision.

This latest form of electron ptychography will enable scientists to locate individual atoms in all three dimensions when they might be otherwise hidden using other imaging methods. Researchers will also be able to find impurity atoms in unusual configurations and image them and their vibrations, one at a time. This could be particularly helpful in imaging semiconductors, catalysts and quantum materials – including those used in quantum computing – as well as for analyzing atoms at the boundaries where materials are joined together.

The imaging method could also be applied to thick biological cells or tissues, or even the synapse connections in the brain.

HOVER JOINS SURFSIDE COLLAPSE INVESTIGATION TEAM

Concrete expert Ken Hover, Ph.D. '84, professor in the School of Civil and Environmental Engineering, will play a key role on an expert team assembled by the federal government to investigate the June 24, 2021, partial collapse of the Champlain Towers South condominium in Surfside, Florida.

The U.S. Department of Commerce's National Institute of Standards and Technology (NIST) announced the composition of the team, which aims to determine the technical cause of the collapse and, if indicated, to recommend changes to building codes, standards and practices, or other appropriate actions to improve the structural safety of buildings.

Hover will co-lead the investigation's materials science project, which will work to evaluate the strength, appropriateness, uniformity and deterioration of materials used in specific building features and at different floors in the building. These findings will be compared with the characteristics specified in the building design, and the data will be used in the partial collapse analyses and simulation.

"One of the things that makes me a good fit for this team is my extended professional design and construction experience, in addition to my years of teaching and research," Hover said. "I think I can play a valuable role here."

Hover said he feels honored to be part of the newly formed NIST investigation team and is ready to do whatever he can to determine what factors played

Ken Hover, professor in the School of Civil and Environmental Engineering.

a role in the collapse, identify current safety issues and make recommendations to help avoid future failures.

Members of the CROPPS team are pictured on campus. From left: Shannon Spencer, CROPPS program and operations manager; Joyce Van Eck, associate professor at the Boyce Thompson Institute; Abe Stroock, the Gordon L. Dibble '50 Professor in the Robert F. Smith School of Chemical and Biomolecular Engineering; José Martínez, the Lee Teng-hui Professor of Engineering in Electrical and Computer Engineering, and senior associate dean for diversity and academic affairs; Susan McCouch, Ph.D. '90, the Barbara McClintock Professor in the College of Agriculture and Life Sciences; and Bruce Lewenstein, professor of communication, CALS.

$25M CENTER WILL USE DIGITAL TOOLS TO 'COMMUNICATE' WITH PLANTS

A new multi-institution, transdisciplinary center will develop systems for two-way communication with plants, allowing scientists to remotely sense a plant's biology and its immediate ecosystem, in hopes of one day using the information to improve plant growth.

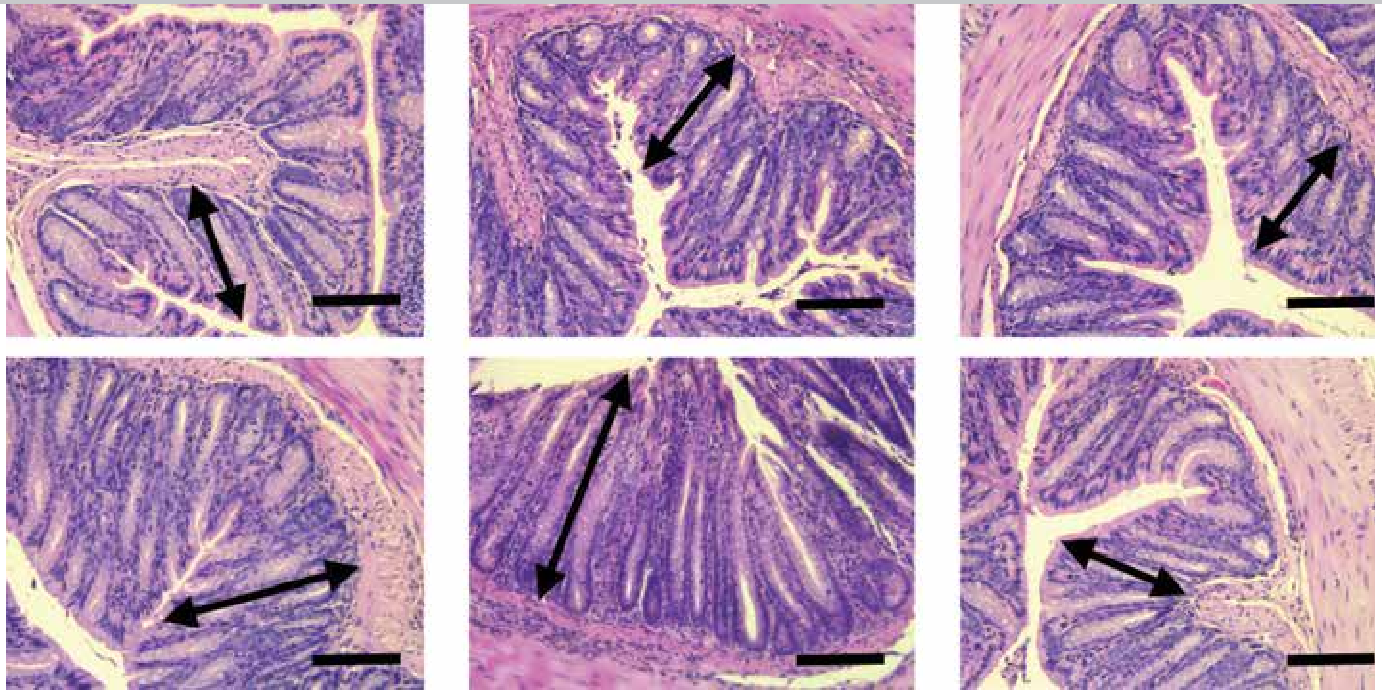
The new Center for Research on Programmable Plant Systems (CROPPS), funded by a five-year, $25 million National Science Foundation grant, aims to grow a new field called digital biology. It will be led by researchers from the College of Engineering, College of Agriculture and Life Sciences, and the College of Computing and Information Science.

CROPPS will develop technologies connected to the internet and the cloud – creating an Internet of Living Things – to listen to and learn how plants sense and respond to their environments. As these tools develop, they will be made more interactive. The ultimate goal is two-way communication, where scientists receive information and respond to what a plant needs, or to work with the plant's genetics to affect physical outcomes.

"At the heart of this project are plants endowed with new ways of expressing biological processes – including hidden processes that occur inside tissues or underground – through a readable signal that we can develop technologies to capture," said Abraham Stroock '95, CROPPS co-director and the Gordon L. Dibble '50 Professor in the Smith School of Chemical and Biomolecular Engineering.

At first, the center will work toward developing digital plant sensing tools connected to the cloud and the internet. Some early examples include work by Stroock to develop nanoscale sensors and fiber optics to measure water status just inside a leaf's surface, where water in plants is most actively managed. Such a tool would be minimally invasive and will not only advance understanding of basic plant biology, but offer information for breeding more drought-resistant crops.

José Martínez, the Lee Teng-hui Professor in the School of Electrical and Computer Engineering, is a principal investigator and Hakim Weatherspoon, associate professor of computer science, will serve as an associate director of the center.



Geographic differences in the microbiome lead to differences in susceptibility to C. rodentium infection in humanized mice. Representative images of H&E-stained colon sections of control and infected mice 14 days after infection. The arrows depict average crypt length with hyperplasia observed in the US and FIJI mice. Scale bar represents 100 μm. Control top, infected bottom. Left to right: US, Fiji, Guatemala.

GEOGRAPHIC DIFFERENCES IN GUT MICROBIOTA BOOST IMMUNITY

The gut microbiome is a diverse environment, jam-packed with up to 1,000 different species of bacteria. Human populations around the globe have significant differences in the composition of their gut microbiomes, which can impact their health in unique ways that have not been completely understood.

Complicating matters, gut microbiome research has predominantly focused on health subjects important to high-income countries like the United States and in Europe, leaving out much of the world's health problems.

A Cornell-led project has sought to fill in some of these gaps by studying mice that were "humanized" with microbiota from three global populations – in the U.S., Fiji and Guatemala – and their resistance to severe intestinal infection. The researchers found that microbial differences alone can impact immune responses, and quite quickly at that. They also observed that housing the mice together so that they shared microbiota helped mice with low resistance to infection become more resilient.

The project, done in collaboration with researchers from the Center for Studies of Sensory Impairment, Aging and Metabolism in Guatemala, grew out of a 2018 Cornell workshop on microbes and global health organized by Ilana Brito, assistant professor and the Mong Family Sesquicentennial Faculty Fellow in Biomedical Engineering in the College of Engineering, who led the team.

A range of factors can influence disparities in gut microbiome composition, from genetics and diet to antibiotic use, sanitation infrastructure and exposure to infectious diseases. It can be difficult to control for so many variables, so the researchers took microbiome samples from the three global populations and put them in 30 germ-free mice, then exposed them to Citrobacter rodentium, a model for severe intestinal infections like E. coli, to see how they responded.

"You get very different immune responses of these microbiomes in these different mice that led them to be either more or less resilient to infection," said Brito, who noted that Guatemala microbiota proved most resistant, followed by the U.S., then Fiji. "The interesting thing was they are exhibiting these differences in resilience to infection in a very short time. This isn't something that's happening over generations."

The researchers also exposed the mice to Listeria monocytogenes, but did not see similar responses, which suggests the microbiome is affecting certain attributes of the immune system and not others, Brito said.

In a follow-up experiment, the researchers co-housed mice with microbiomes from the three global regions and exposed them to C. rodentium. Because mice consume each other's stool, microbiota pass between them, essentially mimicking the way a human's microbiota composition can change when they travel, change their diet or permanently immigrate. The researchers found that less resilient mice benefited from the sharing of microbiota.

The ability to transfer resistance to infection demonstrates the potential of harnessing the microbiome for therapeutic treatments.

"I think the broader point is that we should be studying the health effects of microbes that we find outside of our backyard," Brito said. "How could we improve people's health with microbiome interventions throughout the world, for different types of health problems? It warrants a global view."

CORNELL SCIENTISTS TO JOIN TEAM FOR LIVE VOLCANIC ERUPTION

The newly erupted Cumbre Vieja volcano on La Palma in the Canary Islands illuminates the night sky in early October.

Among the Cornell faculty, Esteban Gazel arguably conducts the hottest research. But this time the geochemist should be safe from magma heat.

Gazel, associate professor in the Department of Earth and Atmospheric Sciences, and doctoral student Kyle Dayton joined a small, elite team of international researchers on Oct. 21 at the newly erupted Cumbre Vieja volcano on the island of La Palma in the Canary Islands – off the coast of western Africa.

"The opportunity to be near an active volcanic during an eruption is rare," Gazel said. "Volcanoes erupt all the time, but not all volcanoes are accessible. This volcano has been well monitored, well understood and we have enough background data now to validate any new measurements."

Dayton and Gazel will collect on-site micro and nano samples of the air carried by the wind to Tenerife, the largest of the Canary Islands, as well as the island of La Palma, as part of a NASA-supported project to investigate the global effects of volcanic ash on the Earth systems in collaboration with department faculty members Natalie Mahowald, the Irving Porter Church Professor of Engineering; and Matthew Pritchard, professor of earth and atmospheric sciences. They will also sample crystals containing glass inclusions to determine the volcano's volatile budgets, including carbon dioxide emissions.

Gazel calls Cumbre Vieja's Sept. 19 eruption a non-aggressive one. People living around the volcano have been evacuated, but many La Palma buildings and infrastructure in the lava path will be destroyed. The volcano erupted mildly in 1971 and in 1949; Gazel said the 2021 eruption shows no signs of slowing down.

Said Gazel: "All of this matters so that we can understand the internal dynamics of a planet and the mechanism behind eruptions. Volcanoes act as probes to understand the interior of the Earth."

RESEARCHERS RECEIVE $5.4M TO ADVANCE QUANTUM SCIENCE

Cornell researchers and their collaborators will continue to advance quantum science and technology thanks to $5.4 million in new funding from the U.S. Department of Energy (DOE).

The project "Hybrid Quantum Magnonics for Transduction and Sensing" received $1.8 million of the funding and is led by Greg Fuchs, Ph.D. '07, associate professor of applied and engineering physics.

The research aims to make advances on one of the fundamental challenges of solid-state quantum technologies: networking quantum processors together to exchange information. The project will also focus on quantum-enhanced sensing, by using magnons – the magnetic excitations in ultra-low damping materials – to connect superconducting circuits to individual quantum bits. By combining desirable properties from different quantum systems, the hybrid systems will create new opportunities for enhanced quantum functionality, including the control of large-scale quantum states, new interconnects for solid-state quantum bits, and the ability to control the direction of quantum information flow.

"I'm excited to push magnetic materials into the quantum limit to enable new ways to make quantum devices," Fuchs said. "The project is fundamental, but the opportunity is to take advantage of the fact that magnetic materials are nonreciprocal, meaning they can enforce 'one-way' interactions. That is currently difficult in quantum systems."

The Cornell project "Planar System for Quantum Information" received $3.6 million and is led by Jie Shan, professor of applied and engineering physics (Cornell Engineering).

Shan and collaborators will focus on developing moiré materials for quantum simulation, which are formed by overlaying layers of 2D materials with a small twist angle or lattice mismatch. Electrons can tunnel between traps created by the moiré structure, presenting unprecedented possibilities for simulation of interacting quantum particles in a solid-state platform.

The project will also develop advanced methods for material synthesis and 2D assembly, such as bulk crystal growth using a flux synthesis method and the creation of tailored 2D heterostructures with on-demand control of rotation angle using dry transfer techniques.

John A. Swanson '61, M.Eng. '63, left, speaks with Lynden Archer, the Joseph Silbert Dean of Engineering, in Duffield Hall on Oct. 14.

ANSYS FOUNDER SWANSON RECEIVES ENGINEERING ALUMNI AWARD

When John A. Swanson '61, M.Eng. '63, launched his own company, Swanson Analysis Systems Inc., in 1970, he hoped it would give him the opportunity to work with a handful of employees who shared his enthusiasm for software.

He did not know it would grow into what is now known as ANSYS Inc., a global leader in developing engineering simulation and technologies used by engineers and designers across a broad spectrum of industries.

"Don't try to predict life," Swanson told an in-person and virtual audience from a stage in Duffield Hall on Oct. 14.

Swanson, a known innovator in the application of finite-element methods of engineering, was honored with the 2021 Cornell Engineering Distinguished Alumni Award in recognition of his extraordinary leadership and vision, and the distinction he has brought to the college.

"John's boundless enthusiasm for engineering education, and his exceptional generosity with his time, knowledge and resources, have had an enduring impact here at Cornell and beyond," said President Martha E. Pollack, who highlighted the breadth of areas that Swanson and his wife, Janet, have supported at Cornell and elsewhere.

Among the university's foremost benefactors, the Swansons have given generously to the College of Engineering and the College of Veterinary Medicine, with gifts to programs – including the Swanson Laboratory for Advanced Simulation – as well as faculty support, scholarships and capital projects. He has also served on multiple advisory councils, including the Engineering College Council.

In a lively, in-person discussion with Lynden Archer, the Joseph Silbert Dean of Engineering, Swanson touched on his small-town upbringing, his success in business, his recent focus on renewable energy and his long-standing commitment to philanthropy.

"My opinion is that engineering is the world's greatest career," Swanson said.

Elected to the National Academy of Engineering in 2009, Swanson received his bachelor's and master's degrees in mechanical and aerospace engineering from Cornell, and his Ph.D. from the University of Pittsburgh, where the Swanson School of Engineering is named in recognition of his involvement and support. He began his career in 1963 at Westinghouse Astronuclear Laboratory.

After serving as president and CEO of ANSYS, Swanson sold the company in 1994. More recently, he has shifted his attention to renewable energy, including solar and biodiesel enterprises. He is a developer of Green Key Villages in Lady Lake, Florida, the only "net zero energy" home development in the area.

SCIENTISTS HARNESS MACHINE LEARNING TO LOWER SOLAR ENERGY COST

A Cornell-led collaboration received a $3 million grant from the U.S. Department of Energy to use machine learning to accelerate the creation of low-cost materials for solar energy.

The three-year project, "Formulation Engineering of Energy Materials via Multiscale Learning Spirals," is led by principal investigator Lara Estroff, professor of materials science and engineering, in partnership with co-PI John Marohn, professor of chemistry and chemical biology. Co-PIs include Paulette Clancy, the Samuel and Diane Bodman Chair of Chemical Engineering Emerita, now at Johns Hopkins University.

The collaboration originated in an earlier project, funded by the Cornell Center for Materials Research (CCMR), which brought together a team that included Estroff's expertise in crystallization and structural characterization and Clancy's computational modeling of semiconductor materials, to explore a class of materials called hybrid organic-inorganic perovskites – crystal structures that can efficiently convert light into electricity.

This type of perovskite is especially noteworthy because it has the potential to be grown from solution, rather than processed with high temperature, and so can be manufactured via low-cost methods, such as inkjet printing and slot-die coating, on a wide range of substrates, Estroff said.

This makes perovskites bright candidates for photovoltaic cells. The reason the material is still in the lab and not in the solar panels on your roof is threefold: perovskites are difficult to scale up, they are unstable, and they are challenging to reproduce reliably.

"We think we can solve all of these problems," Marohn said. "This is like the dream team for solving them. You have people who have made breakthroughs in various areas. And now we get to put all of these breakthroughs together."

Estroff's lab, which has done extensive work in biomineral growth, previously observed how the crystalline precursors develop, which gave the researchers the idea that they might be able to steer how perovskites crystallize into a stable form that can operate better. The lab's work with Clancy found they could compute how the precursors form in different solvents, which suggested a possible role for large-scale machine learning to predict material synthesis. Marohn's group showed, by measuring the material's electronic properties, that when light is shined on perovskites, not only are electrons knocked loose, triggering electronic conductivity, but so are ions. The ionic conductivity could be one reason why the material has been unstable.

The role of machine learning is particularly crucial for growing perovskites that will have optimal performance in devices.

"If you start writing down the number of different combinations of atoms, and allow for substitutions, you very quickly reach half a million different compounds that you could make. And then if you add all the different solvents that you could use to make them, it just explodes," Estroff said. "Experimentalists like myself could never make all of the different materials that are possible. The diversity of compositions and processing routes makes this a problem waiting for machine learning and data science."

Photovoltaic solar panels at the Solar Farm on Snyder Road.

News clips abbreviated from Cornell Chronicle articles written by Chris Dawson, Blaine Friedlander, David Nutt, Syl Kacapyr and Krishna Ramanujan. For more news, visit engineering.cornell.edu.

NANO STORIES

OVERHEARD

Engineering Alumna Rockets to Netflix Baking Competition

"For me, the entire experience, especially coming from the engineering world, was really eye-opening. I didn't realize how much engineering actually goes into baking. But ultimately, it also got me out of my comfort zone, which can be really important."

- Renee Frohnert, M.Eng. '19, after appearing on Netflix's new baking-engineering competition show "Baking Impossible."

TEACHING EXCELLENCE

203 Phillips Hall 'flips' for active learning

In 2021, Phillips Hall Room 203 was 'flipped' into an active-learning classroom thanks to renovations that converted fixed seating to mobile tables and chairs for 64 students. The room renovations added white boards on the side and back walls, additional electrical outlets for student devices, new audio-video equipment, and acoustical ceiling tiles to absorb noise from group discussions.

AROUND CAMPUS

Big Red Band performs on Ho Plaza

TJ Sheppard '22, who studies biological and environmental engineering, and Jessica Sakamoto '22, who studies applied and engineering physics, perform with the Big Red Band on Cornell Move-In Day.

TRENDING

The Class of 2020 Returns

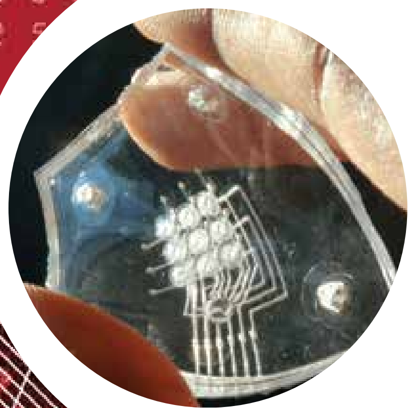
Sixteen months after receiving their degrees, the Class of 2020 – whose final year at Cornell was upended by the COVID-19 pandemic – donned caps and gowns on Sept. 19 for an in-person Commencement. This photo of the Cornell Engineering procession reached 12,635 people and received 1,256 likes on Instagram - @CornellEng.

IN THE FIELD

Geophysicist sprints to monitor quake aftershocks in Alaska

When an 8.2-magnitude earthquake struck off the coast of Chignik, Alaska, on July 29, geophysicist Geoffrey Abers did the logical – if not simple – thing. He raced to Alaska with a group of collaborators to record its aftershocks. The data they collect could provide new insight into the mechanics of crustal faults and possibly help researchers understand and anticipate future earthquake clusters. "This was the biggest earthquake in the U.S. since 1965," said Abers, the William and Katherine Snee Professor in Geological Sciences and chair of the Department of Earth and Atmospheric Sciences. "There are very few good recordings of earthquakes this large anywhere on the planet. So that's a big motivation for trying to understand the sequence as sort of an archetype."

MAKER'S CORNER



Combustion creates braille display for electronics

Imagine an iPad or a Kindle for the blind, with inflatable braille that changes shape under a user's touch. A collaboration led by Rob Shepherd, associate professor of mechanical and aerospace engineering, has made a crucial component for such a technology: a haptic array of densely packed actuators that cause silicone membrane "dots" to pop up when triggered by combustion. The technology is also stretchable and conformable, and the researchers anticipate it could be incorporated into a range of applications, such as soft robots and wearable virtual reality equipment that simulates artificial touch. The biocompatible components could also be used for surgical tools that manipulate tissue or open blocked passageways in medical patients.

By Jackie Swift

PUSHPRINT

PIONEERING THE 3D-PRINTING TECHNIQUES OF TOMORROW

In his early years at Cornell, Larry Bonassar, the Daljit S. and Elaine Sarkaria Professor in Biomedical Engineering, and his colleagues engineered a process for making printable materials that can also carry living cells. "If you do it right, the material is literally alive when it comes off the printer," he says. That innovation opened the door for a pioneering career in biomedical research that, for two decades and counting, has largely been centered around 3D printing.

The Bonassar group initially printed cartilage, an a-vascular tissue that does not normally have blood vessels. In 2017, the researchers received some attention for 3D printing human ears, which are essentially pure cartilage. "The idea that you could grow cartilage in the right shape and use it to replace a body part was first brought up in the mid '90s," Bonassar says. "But the technology that's necessary to do it, the engineering to do it, requires the precision and the reproducibility of something like a printing process. That also makes it customizable and scalable."

3D printing is one of the great engineering innovations of the early 21st century. It has been applied to everything from biomedicine to architecture, and scientists continue to explore the full range of possibilities enabled by the process. Much has been achieved, but — if predictions hold true — there is much more to come. As researchers devise processes and techniques to push 3D printing technology to the next level for a range of materials, many next-generation breakthroughs are likely to emerge from Cornell Engineering.

Bonassar and his colleagues, for example, have applied their expertise to printing increasingly complicated cartilage. Once they had practiced on the ear, they turned to intervertebral discs—the soft tissues between vertebrae in the spine—which have different types of cartilage on the outside and inside of the disc. The overall goal is to eventually replace diseased or injured cartilage in human beings with 3D printed implants. "Living 3D-printed body parts like these have not yet been implanted in humans," Bonassar says. "But I expect clinical trials to start in the very near future."

In the meantime, the Bonassar group is developing a new generation tissue printer that can monitor itself by taking measurements on the material as it is depositing it. "The real challenge is quality control," Bonassar explains. "We're working on closed-loop control: a printer that is able to count cells and determine their viability while we're depositing them and that can confirm the implant is sterile as we're making it, so that in the end, we make exactly what we wanted to make."

Quality Control

Monitoring and controlling the printing process is an issue across the spectrum of 3D printing, also known as additive manufacturing. It is central to the research of Atieh Moridi, assistant professor in the Sibley School of Mechanical and Aerospace Engineering. In an effort to better understand the complex physics of the 3D printing process, Moridi uses the Cornell High-Energy Synchrotron Source (CHESS), a high-intensity X-ray research facility, to watch while a 3D printer lays down deposits of metallic materials. She is able to follow the fabrication process in more detail than ever before and to identify defects as they occur.

> **"THERE ARE ENDLESS OPPORTUNITIES TO EXPLOIT 3D PRINTING PROCESSES, AND WE ARE JUST STARTING TO SCRATCH THE SURFACE OF WHAT'S POSSIBLE."**
> **— Atieh Moridi**

That work led to a National Science Foundation CAREER Award. But even while Moridi is making waves with her CHESS-assisted monitoring techniques, she is well aware that a sophisticated research facility like CHESS is not available in industry settings. To boost the adoption of 3D printing by manufacturers, she sought to create a cheaper, more accessible monitoring technique. As part of that endeavor, she now serves as mentor to a NASA University Student Research Challenge project that seeks to combine the results of CHESS X-rays with those of acoustic emission sensors to identify errors during the additive manufacturing process.

"We want to acquire signals from both of these sources and correlate them, what I call concurrent watching and listening to the additive manufacturing process" Moridi says. "We watch with the synchrotron, acquiring hard-proof physics, and we listen with acoustic emission sensors. If there's a defect, we will hear that in the acoustic signal, and we will know what that means because we are watching the process with X-rays."

The overall project goal is to build up a database of signals correlated to specific types of defects. "We can essentially train people so when they listen to the additive manufacturing process, they will know if this is a good print or a bad print, or if this is a good layer or a defective layer," Moridi says. "If there is a defective layer, in the future we hope to be able to add some corrective measures during the printing process, maybe remove the defective layer and redo it."

Moridi is also researching 3D printing at lower temperatures, known as cold-spray printing. This technique avoids the residual stresses that can weaken a part printed with the current melt-based processes used for metal additive manufacturing. "Normally we rely on melting to fuse powder particles together," she explains. "In this project, we use kinetic energy for bonding, rather than thermal energy; essentially we're printing at supersonic speeds that smash the materials together and cause fusing of the particles."

Assistant Professor Atieh Moridi (left) and doctoral student Chenxi Toby Tian operate a 3D printer in the Laboratory for Advanced Materials and Manufacturing.

Professor Lawrence Bonassar holds a 3D-printed artificial ear.

In the course of that research, the Moridi group also explored the ramifications of intentionally printing defects, causing the resulting structure to be porous. They then tested the feasibility of using the porous structures, made of titanium alloy, as biomedical implants specifically for encouraging new bone cells to grow inside them. "We showed that cells actually like these kinds of structures" she says. "The porous networks give enough space for bone to grow inside the pores and integrate the implant so there is less incidence of implant loosening."

Also, unlike solid metallic implants—which are many times stiffer than bone and therefore bear more of the load, weakening the surrounding bone in the process—the porous implants can be printed to match bone strength, Moridi says. Both the bone and the implant then carry equal amounts of the load.

Scaling Up

Scaling up the size of 3D printed materials — from the dimensions of a human ear to the size of, say, an office building — is another challenge of the technology. Sriramya Duddukuri Nair, assistant professor of civil and environmental engineering, is looking into the potential of layer-by-layer printing to solve some of the most pressing 21st century construction issues. Nair, who specializes in novel cementitious materials, is attracted to the technique for its flexibility as well as its potential for real-time quality control.

The traditional process for constructing large-scale structures from concrete depends on building a wooden formwork first and then filling it in with concrete. These frameworks limit the shapes that structural members can assume. They also often end up in landfills after one use, especially if they are created to hold a specialized shape specific to a particular architectural or structural component.

"But with 3D printing, you're not limited in the shape the form can take because it removes the need to use formwork," she says. "It gives you more flexibility on the shape, and it increases ease of construction. 3D printing is here to revolutionize our way of thinking about structures and to open up new possibilities."

Like Bonassar in biomedical engineering, Nair has identified the need for better printing materials. In Nair's case, the desired material is steel-fiber-reinforced concrete, which is able to withstand heavier loads. Unlike Bonassar's focus on perfecting bio ink, however, Nair's conundrum is how to engineer the printing head, or extruder, so that it can handle the thick material.

The problem came to light when the Nair group began to shop around for a 3D concrete printing system for Cornell's Bovay Civil Infrastructure Laboratory Complex. "The printing heads available can only print with cement, sand and flexible polymeric fibers," Nair says. "You can't print with steel fibers. So, there are a lot of challenges on what can be printed because of the pumping systems and the extruder head capabilities."

Assistant Professor Atieh Moridi operates a 3D printer.

A cement mix is deposited from a 3D-printer head in the lab of Assistant Professor Sriramya Nair.

The Nair group has taken on the challenge of engineering a new extruder head capable of printing with steel-fiber-reinforced concrete. At the same time, Nair will be joining with Greg McLaskey, assistant professor of civil and environmental engineering, who specializes in work with ultrasonic sensors, to develop a method for real-time evaluation of 3D printed concrete so that errors can be identified and fixed as they happen.

Further down the line, autonomous robotic 3D printers may be employed to build housing and infrastructure, Nair says, which could result in construction jobs becoming safer and less stressful on the human body. "There's predicted to be a shortage of construction workers in the future because these types of jobs are physically hard and don't pay well," she says. "With autonomous 3D printing, construction jobs may become more skilled and higher paying because workers will be handling robots and using data to analyze if everything is going to plan."

Looking Forward

Advances in 3D printing are expected to continue accelerating at scales both large and small. For Bonassar, the big frontier in 3D tissue printing is figuring out how to print vasculated tissues like kidney, liver or brain. Breakthroughs in that area will probably incorporate advances in cell-based therapy—the infusion of stem cells and other types of reprogrammed cells directly into the body, he says.

"With direct infusion of cells, the challenge is how to be sure that the cells are going where you want them to, that they're staying where you want them to engraft, and that they are organizing relative to each other in the way you want," Bonassar says. "The beauty of 3D printing is that you can address all of those issues at once. You can arrange them in the material the way you want, and you can use materials that will engraft in the target area of the body and encourage blood vessels to grow so that the cells stay alive and connect with the rest of the system."

Meanwhile, others are thinking about what the future of 3D printing means for the production of larger structures. "For example, do we need all those dense solids that make up a bridge? Probably not," Moridi says. "They are like that because we can't affordably make these structures hollow. There are endless opportunities to exploit 3D printing processes, and we are just starting to scratch the surface of what's possible."

Assistant Professor Sriramya Nair (top left) and her students operate a 3D printer that deposits cementitious materials in the Bovay Laboratory Complex.

PRIME TIME

By Tom Fleischman

First therapeutic clinical trial of C'Dots underway

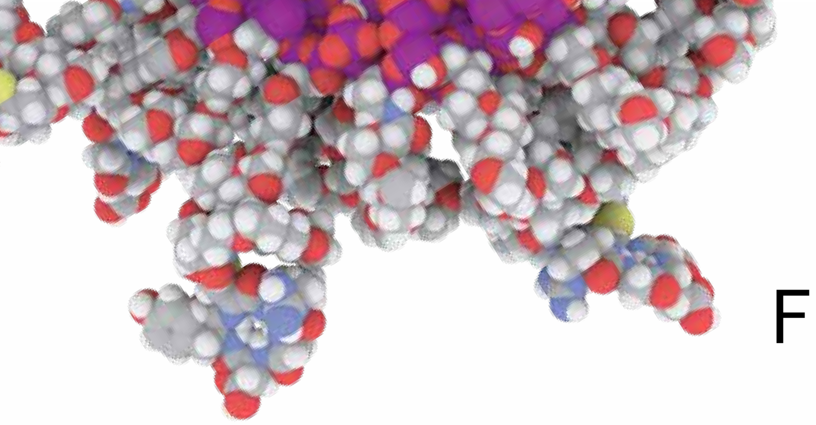
From the very beginning around 20 years ago, "Cornell dots" – silica-encased fluorescent nanoparticles, developed in the lab of Ulrich Wiesner, the Spencer T. Olin Professor of Engineering – were seen as having great potential as biological markers. C Dots were also touted as having possible applications in displays, optical computing, sensors and microarrays such as DNA chips.

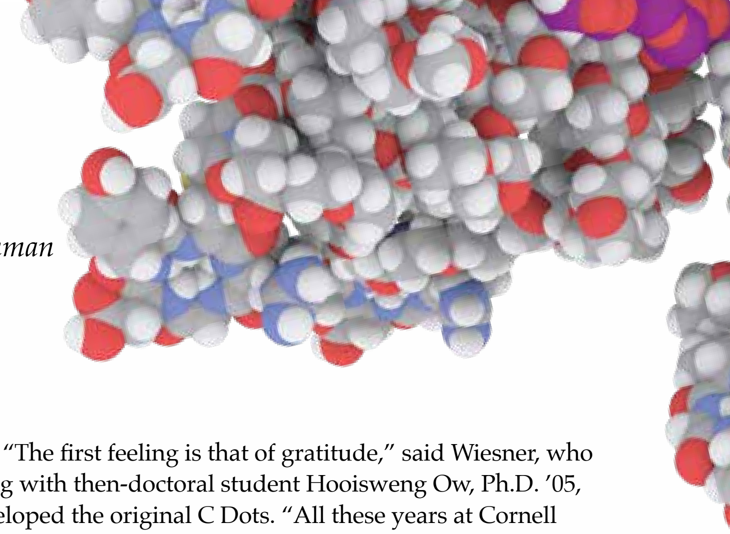
The technology has been refined and improved since its unveiling in 2005. C Dots have been used to create the world's smallest laser and, in collaboration with researchers at Memorial Sloan Kettering (MSK) in New York City, have shown the diagnostic ability to find tumors; a new version – Cornell Prime Dots, or C'Dots, synthesized in water – was armed with nano-sized antibody fragments, and in separate studies actually induced, without attaching a drug, a form of cell death in tumors.

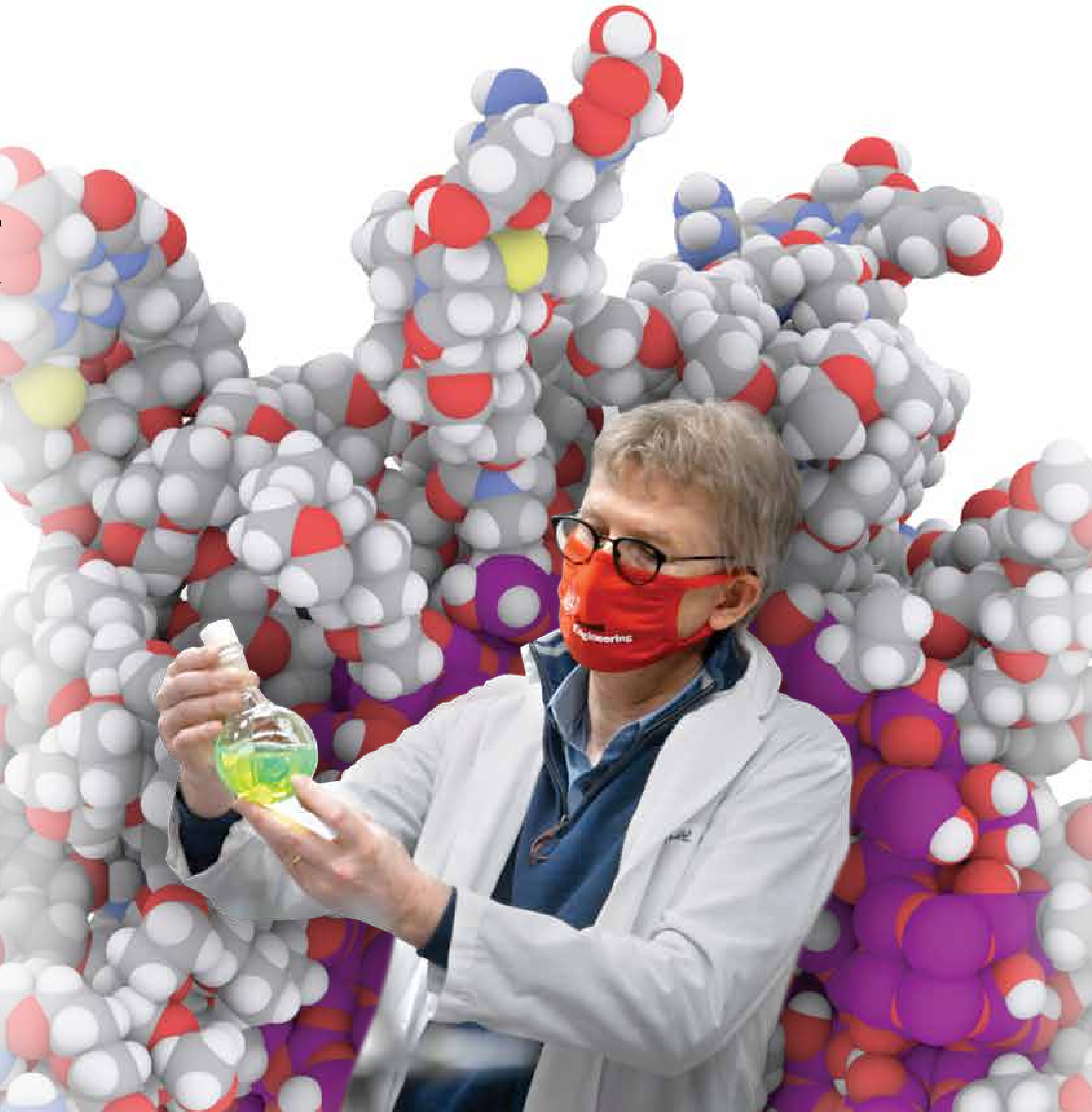
Now C'Dots, proven safe and effective in three previous diagnostic human clinical trials, have just begun their first therapeutic trial, having been further developed by Elucida Oncology, Inc., a New Jersey-based biotechnology company co-founded by Wiesner.

"HAVING DEVELOPED A TECHNOLOGY THAT HELPS IMPROVE THE LIVES OF CANCER PATIENTS WOULD BE INCREDIBLY REWARDING."

—Ulrich Wiesner







"The first feeling is that of gratitude," said Wiesner, who along with then-doctoral student Hooisweng Ow, Ph.D. '05, developed the original C Dots. "All these years at Cornell and beyond, I have been able to work with so many talented individuals whose work has led, in a highly interdisciplinary effort, to the development of these particles to the point where they are now. I am particularly thankful for many years of a very close and excellent collaboration with my colleague, Michelle Bradbury, at MSK Institute and Weill Medical College of Cornell University. It was a long voyage, with lots of setbacks for our team."

"This is a major turning point in the evolution of the technology," says Kai Ma, Ph.D. '15, co-founding scientist and CTO, and one of five key personnel at Elucida with ties to Cornell. "I feel very proud that our team is able to successfully close a series of challenging gaps between academia and the pharmaceutical industry to advance the C'Dot technology from the exciting innovation in the labs to real patient care and market success."

The newest iteration of C'Dots is what the Elucida team refers to as CDCs – C'Dot drug conjugates, the nanoparticle with dozens of drug molecules attached. It is being developed under the product codename ELU001 as a treatment for patients with advanced, recurrent or refractory cancers overexpressing folate-receptor alpha, including ovarian, breast and lung cancers.

The company announced Sept. 17 that it had completed the initial dosing of the first patient in its Phase 1/2 clinical study of ELU001. Geno Germano, president and CEO of Elucida, says the company has "taken a meaningful step closer to a new frontier in precision oncology" with the beginning of the current trial.

Other Cornellians at Elucida:

- Paul Rudick '90, vice president of commercial development and business operations;
- Melik Turker, M.S. '15, Ph.D. '19, head of materials science and production;
- Fei Wu, Ph.D. '16, head of materials technology development; and
- Tom Gardinier, Ph.D. '19, head of materials analysis.

Turker, who has been working on C'Dots for more than eight years, is excited about the technology moving from a diagnostic to a therapeutic realm.

"These trials are an important milestone for our technology," he says, "both for making it into the clinic to be tested for the treatment of cancers as an inorganic hybrid nanoparticle platform, and for showing the scalability of our nanoparticle chemistry."

C-Dots being produced in the laboratory of Professor Uli Wiesner.

Target or Clear

Wiesner's mission to improve cancer therapy via Cornell dots is highly personal – his father died of the disease in 1984 – and he's understandably passionate about Elucida's CDCs.

One key to C'Dots, said Wiesner, a member of Elucida's board of directors, is their ability to be efficiently cleared from the body via the kidneys with minimal off-target accumulation.

"With Michelle, we developed this [trademarked] 'Target or Clear' paradigm," he says. "They either target the tumor, or they get out and do not accumulate at off-target sites in your body. Therefore, they are expected to substantially reduce side effects, relative to previous [therapeutic] platforms."

The reason is C'Dots' size – approximately 5 to 6 nanometers, about a third the size of antibody drug conjugates (ADCs), a comparable therapeutic delivery vehicle. This allows for both penetration of solid tumors and clearance through the kidneys.

Penetration of the solid tumor means quicker destruction of tumor cells, Wiesner says.

"Because C'Dots are so small, they also diffuse better," he says. "They can basically get through all of the tumor, not just the periphery, which is important because if you only get to the periphery, then the tumor shrinks from outside in, which takes a long time. But if you can diffuse through the entire tumor tissue, you can basically begin disintegrating the whole tumor from day one."

Elucida's technology features a 10-step process in which C'Dots either find their mark or are eliminated. After injection and circulation in the bloodstream, the CDCs find the tumor, which by nature has a porous surrounding vasculature due to rapid growth, a hallmark of cancerous tissue.

CDCs then diffuse through the tumor microenvironment in order to specifically target tumor cells. This is key: The better CDCs diffuse through the entirety of the tumor, the better they can target cells throughout the tumor, and not just those on the surface layer.

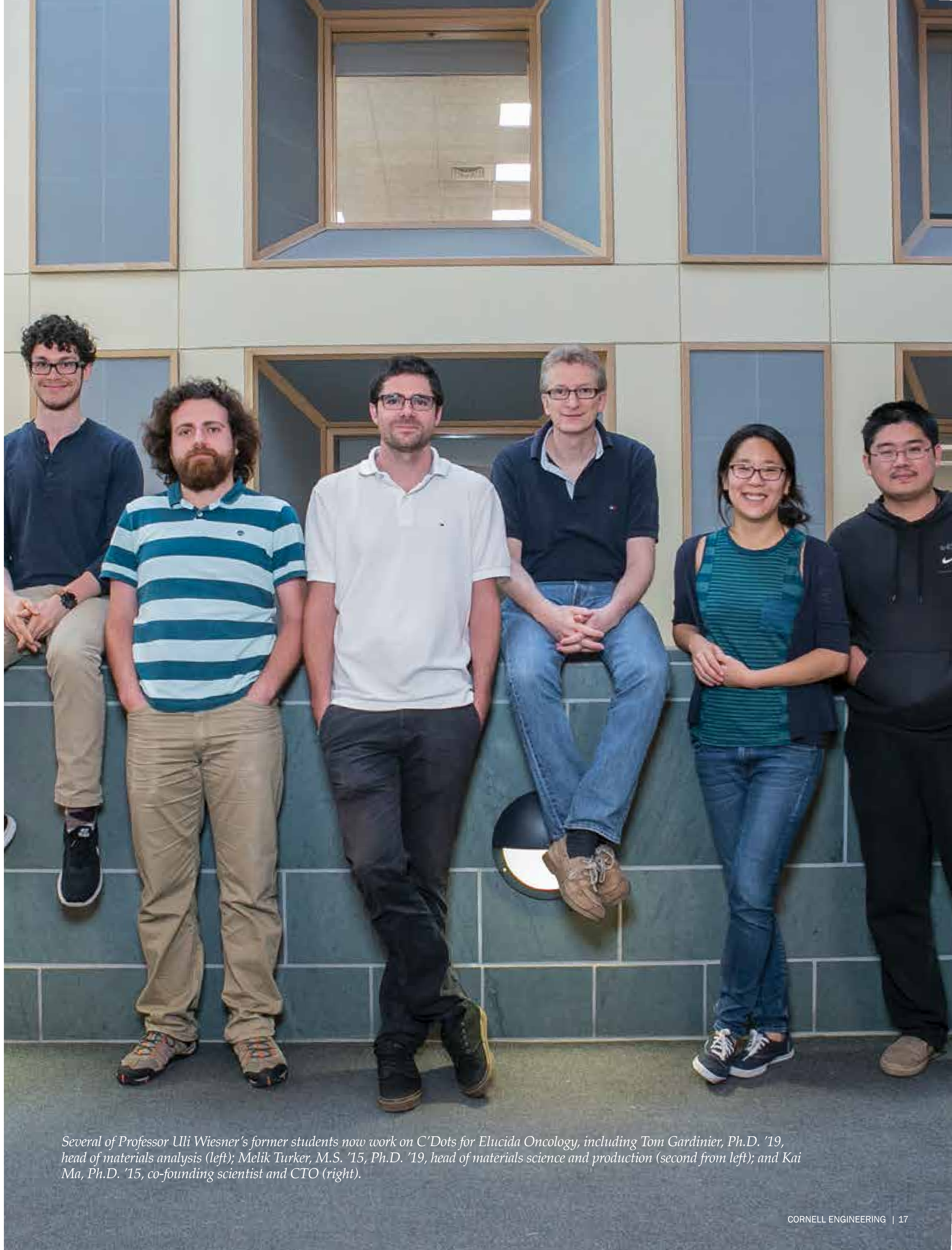
"Target or Clear" leads to efficient biodistribution; accumulation in the tumor is maximized, while off-target accumulation (in the liver, for example) is minimized, reducing the potential for negative side effects such as those often suffered by chemotherapy patients.

Despite their ultra-small size, C'Dots can be armed with a payload of up to 80 molecules of synthetic drugs without compromising the desired targeting and pharmacokinetic properties. In comparison, typical ADCs only carry four drug molecules.

The reason for the superior drug capacity? It's the hydrophilic polyethylene glycol (PEG) shell, which provides colloidal stability in aqueous solutions, including blood serum. The PEG chains are arranged somewhat perpendicular to the silica core's surface, in what's called a "brush" conformation.

The drug payload rests in between the PEG chains – the "bristles" of the brush – meaning the hydrophobic drugs don't destabilize C'Dots in solution.

"You can really think of it as a forest, where you have the drugs in between the trees," Wiesner said. "An antibody does not have such a surface brush layer. There are no trees to hide in between, leading to a lower drug loading capacity."



Several of Professor Uli Wiesner's former students now work on C'Dots for Elucida Oncology, including Tom Gardinier, Ph.D. '19, head of materials analysis (left); Melik Turker, M.S. '15, Ph.D. '19, head of materials science and production (second from left); and Kai Ma, Ph.D. '15, co-founding scientist and CTO (right).

Two-part clinical trial

The open-label, multi-center clinical study has two parts:

- **Dose Escalation Safety Study:** The maximum tolerated dose and/or the recommended phase 2 dose (RP2D) will be identified; and
- **Tumor Group Expansion Cohort(s):** Specific cancer types will be evaluated for efficacy and safety at the RP2D.

Part 1 is enrolling patients with advanced cancers known to overexpress folate receptor alpha, including ovarian cancer, endometrial cancer, colorectal cancer, gastric cancer, gastroesophageal junction cancer, triple negative breast cancer, non-small cell lung cancer and cholangiocarcinoma (bile duct cancer).

The most promising tumor types studied in Part 1 will proceed to investigation in Part 2. Ma and the team are hopeful that success in the current trial will "open a new door for us to develop a variety of CDCs" to benefit a wider range of cancer patients.

The technology has come a long way in 20 years, and Elucida – dotted with Cornellians in both the board room and in its Monmouth Junction, New Jersey, labs – is hoping this is just the beginning.

"I am proud to be a part of the team responsible for bringing this material into its first therapeutic clinical trial," Gardinier says. "There is still a lot of work to be completed, however, before the CDCs become an FDA-approved treatment. So in short, while I feel proud of how far we have come, I am looking to the future and the challenges that await us."

Wiesner has a feeling of "cautious optimism," he says, regarding the future of C'Dots.

"Clinical trials are never easy," he says. "There are so many things that can go wrong and that can never be predicted. Of course, we all in the team would be elated to see this technology reach the full approval stage. Having developed a technology that helps improve the lives of cancer patients would be incredibly rewarding."

"THIS IS A MAJOR TURNING POINT IN THE EVOLUTION OF THE TECHNOLOGY. I FEEL VERY PROUD THAT OUR TEAM IS ABLE TO SUCCESSFULLY CLOSE A SERIES OF CHALLENGING GAPS BETWEEN ACADEMIA AND THE PHARMACEUTICAL INDUSTRY TO ADVANCE THE C'DOT TECHNOLOGY FROM THE EXCITING INNOVATION IN THE LABS TO REAL PATIENT CARE AND MARKET SUCCESS."

— Kai Ma, Ph.D. '15

https://youtu.be/DFCpNAsZtPo

Watch a video and animation showing how C'Dots works inside the body by viewing "Third human trial of Cornell dots underway" on the Cornell University YouTube account.

CornellEngineering Online

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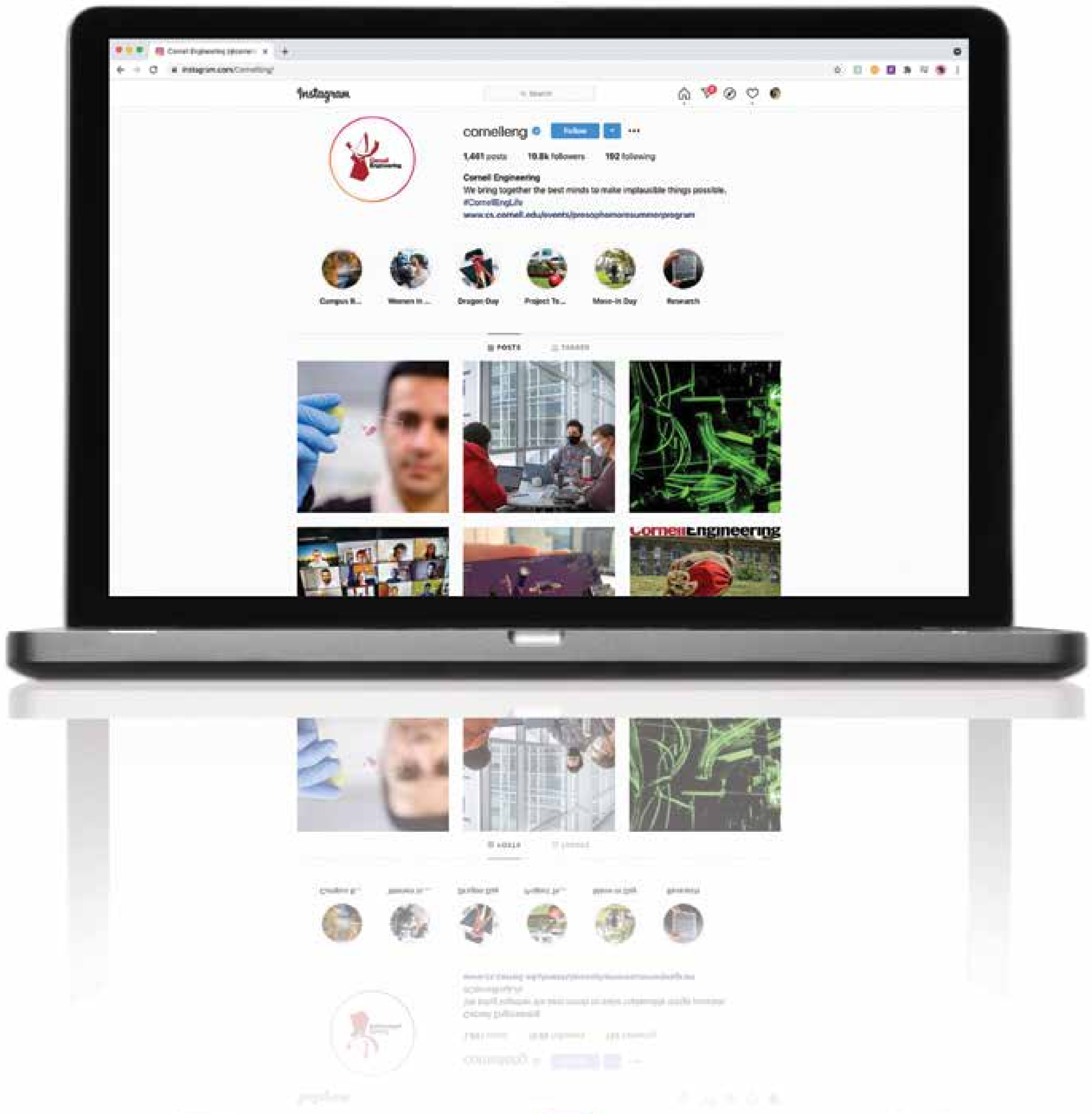

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MEET THE HUMAN TEACHING MACHINES ABOUT TRUST

A CORNELL ENGINEER HELPS POWER THE GLOBAL "DATA-FOR-GOOD" MOVEMENT

By Eric Laine

"Do you trust Eliud Kipchoge to run fast?"

IBM researcher Kush Varshney '04 seemed to veer off topic as he offered this question up to viewers at the beginning of a recent seminar on "What's Next in AI." In support of the assumed affirmative answer, Varshney noted that Kipchoge, the world's fastest marathoner, is highly competent and extremely reliable, having won nearly every marathon he has entered. Kipchoge is also, Varshney noted, very open about his motivation and methods for running at such a high level and also notably selfless in his efforts to support his community.

These attributes are the same qualities that Varshney, the founding codirector of IBM Science for Social Good, an initiative focused on artificial intelligence for social impact, is determined to build into machine learning systems that power computers, software, and robots.

"These attributes map precisely to what we want out of AI systems," he said.

Competence maps to accuracy, Varshney explained, and this is what most researchers have focused on to date. But he believes that trustworthiness is about more than eliminating errors and bias. Other qualities are just as — if not more — important.

For example, reliability maps to distributional robustness and fairness, which is what allows systems to work well in different conditions. Openness maps to explainability, uncertainty quantification, transparency, and value alignment, which enables communication and understanding between machines and their users. The fourth attribute — selflessness — is the one that may have the most impact as AI development proceeds.

"The fourth attribute is about using AI for social good and social impact applications," Varshney said. "And not just that but empowering all people around the world to use AI to meet their own goals."

Varshney's work to infuse AI with the same competence, reliability, openness, and selflessness as Eliud Kipchoge is — as the saying goes — more of a marathon than a sprint. And in many ways, it's a journey he began as an undergraduate at Cornell.

Inspiration Sourced in Cornell ECE

Varshney joined Cornell Engineering's School of Electrical and Computer Engineering at the dawn of the new millennium, a time when new technologies like machine learning, artificial intelligence, and the internet itself were still emerging. "The first time I really had high speed internet was in the dorm," Varshney said. He was drawn to the newness of what was happening in the field of ECE.

"Bridges and tunnels have been around for hundreds of years," he said, "whereas what's happening in ECE is strictly stuff that has not been done before."

Varshney worked on research projects with the late Professor Thomas Parks and Professor Sheila Hemami, who served as his advisor. One summer was spent collaborating with Lockheed in Owego, NY, where he worked with machines designed to analyze images of postal mail, envelopes and magazines, to distinguish the address from the rest of the image.

This work on image segmentation and analysis did not involve machine learning at the time, but it started Varshney on a path that led there. "When you're looking at an image, you're distinguishing the foreground from the background, two dimensions," Varshney explained. "But it turns out that machine learning is actually also trying to partition space."

Part of Varshey's Ph.D. thesis at MIT took image segmentation approaches and applied them to a more generic machine learning problem. "So instead of doing foreground and background, you're analyzing two classes that are just abstract. So that was the connection."

Varshney started thinking about how bias enters these systems around the time that NBA referees were being accused of calling fouls more frequently on Black basketball players. "I started thinking that detection theory is all about the same tasks that a basketball referee is doing."

Humans tend to categorize people into groups, such as groups of high foulers and low foulers. But referees can't possibly remember every player's actual probability of committing a foul, so those kinds of groupings are prone to error. "If you put this sort of constraint into an optimal decision-making formulation, you end up with unfairness," Varshney said. "And it does predict the sort of bias that was observed."

Varshney set out to better understand how a mismatch between true prior probability and erroneous assumptions causes a degradation in decision making performance. He recalled observing that many examples his Cornell professors would use had some sort of societal aspect to them, and that understanding the impact of your work was part of the ethos of Cornell Engineering.

"Engineering isn't just a math problem," he said. "In anything we do, we should be looking at the end users who will be affected and taking more of a participatory design sort of approach. We do engineering to come up with solutions to help people, but we need to hear from those people."

Building the Future

In 2010, when Varshney came to IBM Research, he saw that the group he joined was very much ahead of the game when it came to machine learning, still a very new technology.

"They were applying machine learning to things like human capital management and health care," he recalled. "It was very enlightening and eye-opening for me that machine learning could be used for many human-centric applications."

Despite offers from other companies, including defense-oriented research labs, Varshney chose IBM because it was cultivating this intersection of societal concerns with machine learning. "There was always this idea that there is a human decision-maker that we're supporting. And so, we always had to make our models understandable by people, and that led us to do more research on how to make those models that humans can understand more accurate."

Soon Varshney began volunteering with a group called Data Without Borders, which later became the digital activism organization DataKind. With support from his manager at IBM, Varshney began work on projects through DataKind designed to connect practicing data scientists with nonprofit organizations looking to improve and optimize their services.

"Once I finished a couple of projects," Varshney said, "I invited my manager to come and see our final presentations, and she got really excited as well. So, in 2015, we sat down and said, let's start something like this at IBM."

Their IBM researchers immediately responded with enthusiasm. They created a fellowship program, brought on summer interns, and over the past six years they have conducted at least 35 different projects with various nonprofit organizations as part of IBM Science for Social Good initiative within IBM Research.

Varshney and his team created a comprehensive open-source tool kit called AI Fairness 360, which helps detect and reduce unwanted bias in data sets and machine-learning models. He's also written a book to be published next year, "Trustworthy Machine Learning," which outlines those four principles of trustworthiness that Varshney believes are the key to developing AI systems optimized for fairness.

Looking back, Varshney sees the origins of engineering for social impact in his experiences at Cornell. "While I was there, this group called Engineers Without Borders got launched, so I could see what was happening," he said. "Now what we're working towards is bringing in people with diverse lived experiences to help inform what problems get worked on and how they're judged and evaluated."

Words from former Cornell President Jeffrey S. Lehman's 2004 commencement address still resonate with Varshney: "May you enjoy the special pleasures of profession; the added satisfaction of knowing that your efforts promote a larger public good."

"I think that's a really good guide for some of the things that I've ended up doing," Varshney said.

IBM Science for Social Good Co-Directors Kush Varshney and Saska Mojsilovic, photo provided.

CornellEngineering

Jonathan Butcher

Matt DeLisa

David Erickson

Chris Hernandez

Kade Keranen

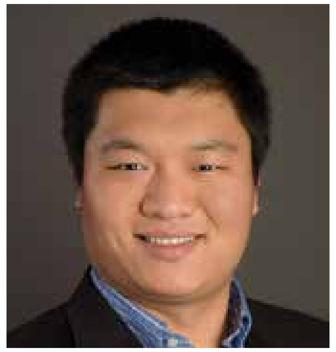
Mark Lewis

Peter McMahon

David Putnam

Hadas Ritz

Michael Thompson



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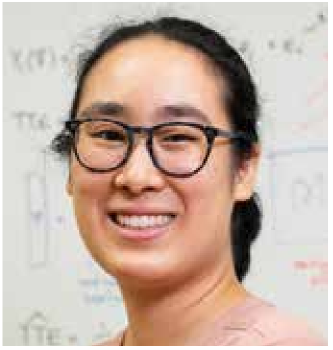


Christina Lee Yu

AWARDS AND HONORS

SCHOOL AND DEPARTMENT ABBREVIATIONS

- **AEP – Applied and Engineering Physics**
- **BEE – Biological and Environmental Engineering**
- **BME – Biomedical Engineering**
- **CBE – Chemical and Biomolecular Engineering**
- **CEE – Civil and Environmental Engineering**
- **CS – Computer Science**
- **EAS – Earth and Atmospheric Sciences**
- **ECE – Electrical and Computer Engineering**
- **MSE – Materials Science and Engineering**
- **MAE – Mechanical and Aerospace Engineering**
- **ORIE – Operations Research and Information Engineering**

Awards and honors received from May through October 2021. Honors received outside of this timeframe appear online.

Jonathan Butcher, professor (BME), was elected a fellow of the American Society of Mechanical Engineers, the highest elected grade of membership within the society, the attainment of which recognizes exceptional engineering achievements and contributions to the engineering profession.

Matt DeLisa, William L. Lewis Professor of Engineering (CBE), was named to the Life Sciences Power 50 list by City & State New York, recognizing the scientists, entrepreneurs and investors driving New York's biotech boom.

David Erickson, S.C. Thomas Sze Director (MAE), was inducted into the Canadian Academy of Engineering. Fellows are elected by their peers, in view of their distinguished achievements and career-long service to the engineering profession.

Chris Hernandez, professor (MAE), was elected a fellow of the Biomedical Engineering Society for his contributions to the field of biomedical engineering, particularly in musculoskeletal microbiology, bacteria mechanobiology, and bone biomechanics. He was also named Educator of the Year (Higher Education) by the Society of Hispanic Professional Engineers in recognition of "the exemplary contributions made by administrators and faculty to improve the learning environment for Hispanic students in K-12 and higher education."

Kade Keranen, associate professor (EAS), was named to the first cohort of Academy Fellows for the AGU Leadership Academy and Network for Diversity and Inclusion in the Geosciences, a two-year professional development program for current and aspiring diversity, equity and inclusion leaders in the Earth and space sciences.

Mark Lewis, director and Maxwell M. Upson Professor (ORIE), was named an INFORMS Fellow by the Institute for Operations Research and the Management Sciences for his impact in advancing minority issues, extended professional service to INFORMS, excellence in academic leadership, and research and teaching in stochastic modeling. Lewis was also elected to the 2022 INFORMS Board of Directors as secretary, and is featured in a new children's book, "Who Is a Scientist?" by Lauren Gehl.

Peter McMahon, assistant professor (AEP), was named a Packard Fellow for Science and Engineering by the David and Lucile Packard Foundation. Using the fellowship funding, McMahon aims to harness the power of photonics to build processors for neural networks that are over 1,000 times more energy efficient than today's most advanced digital processors.

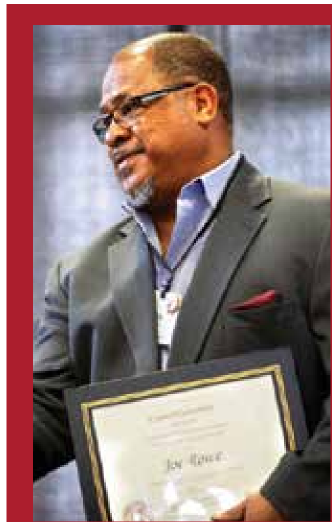
David Putnam, professor (BME, CBE), received a Stephen H. Weiss Award from Cornell, which honors excellence in undergraduate teaching and mentoring. Putnam developed multiple innovative courses from scratch for a new curriculum and engages students with his creative lectures and teaching style, nominators wrote. His student engagement extends to award-winning mentoring and involvement in internships.

Hadas Ritz, senior lecturer (MAE), won the 2021 American Society of Engineering Education National Outstanding Teaching Award, which provides national recognition to an engineering educator for excellence in outstanding classroom performance, contributions to the scholarship of teaching, and participation in the ASEE section meetings and local activities.

Michael Thompson, the Dwight C. Baum Professor (MSE), received a Stephen H. Weiss Award from Cornell, which honors excellence in undergraduate teaching and mentoring. For nearly 25 years, Thompson has taught the fundamentals of thermodynamics, helping students gain an understanding of materials science. Thompson not only cares about his students and their learning, nominators wrote, but turns students into great researchers.

Fengqi You, the Roxanne E. and Michael J. Zak Professor (CBE), was elected to the AIChE Board of Directors to serve as director on the Chemical and Technology Operating Council. He also received the 2021 Sustainable Engineering Forum Education Award by the American Institute of Chemical Engineers to recognize his contributions and accomplishments on sustainability education, and has been admitted as a Fellow of the Royal Society of Chemistry for his significant contributions to the chemical sciences.

Christina Lee Yu, assistant professor (ORIE), received the Intel Rising Star Faculty Award and was named one of 10 "promising early-career academic researchers who lead some of the most important technology research of our time," by Intel.



Joe Rowe: Commitment to Diversity

Joe N. Rowe, director of administration for the School of Civil and Environmental Engineering, was recognized with the 2021 Richard Allmendinger Staff Commitment to Diversity Award from Cornell's Diversity Programs in Engineering (DPE) for his effort to unite the campus community and host open dialogs in the wake of George Floyd's murder.

While many faculty, students and staff were honored with 2021 DPE Awards, Rowe's recognition follows his ongoing efforts to increase belonging across faculty and staff as well as contributing to diversifying the student composition of the college.

"This past year we all saw a visible outcry for racial and social justice in our country," Rowe said. "This opened the door of opportunity for the Cornell Engineering community to come together and have meaningful discussions about diversity, equity, inclusion and belonging. The outcome has increased understanding through sharing many perspectives and the opportunity to learn from each other. I personally have felt more energized and hopeful."

Rowe was also honored by DPE for his work in helping to organize the CATALYST Academy in 2017 and the CURIE Academy in 2018, introducing over 90 high-school students to engineering. In 2019, Rowe was recognized with a Cornell President's Award for Employee Excellence in the category of Thoughtful Leader "for mentoring, challenging and inspiring colleagues to reach their full potential."

Q&A WITH

Two-thirds of all commercial aviation flights are powered by engines for which Mohamed Ali, Ph.D. '97, is responsible.

After earning his doctoral degree in theoretical and applied mechanics from Cornell, Ali joined GE as a research scientist and found a lifelong professional home. Now the vice president and general manager of engineering for GE Aviation, he leads the design, development, certification, and fleet services of GE Aviation's commercial engines. Ali's team – a total of about 5,000 engineers located throughout the world — is also responsible for looking forward and inventing the future of flight with a focus on safety and sustainability.

Ali is married with three children and lives in Mason, Ohio. He also is a member of the board of the Society of Asian Scientists and Engineers, working to advance the organization's mission to promote diversity and inclusion in engineering and science disciplines.

MOHAMED ALI, PH.D. '97,
VICE PRESIDENT & GENERAL MANAGER, ENGINEERING AT GE AVIATION

Can you tell us about your journey to this point in your career?

I was born and raised in Egypt. My father left when I was two, and my mother raised me. In Egypt, being a single mother was rare and carried societal judgment. My mother was always very supportive of me and prioritized excellence in education, which provided a backbone to thrive and succeed. I moved to the United States to attend Cornell University, and I have been fortunate to have a career in a field I am passionate about — aviation.

At GE, I've been coached and supported by many mentors. One piece of advice I received that resonated was that, in order to be successful, I needed to demonstrate confidence and a level of seriousness in myself. I couldn't rely on people noticing my work, which was my belief growing up. To grow and succeed, I needed to be able to connect with my colleagues. I needed to build a network of people who would be able to learn who I was on a human level. People follow people to grow and succeed. In the end, our talents are what make us — and our companies — world class. And talents produce products.

What makes you proud to be a Cornell alumnus?

Arriving in the United States and finding an amazing mix of students from different nationalities and socioeconomic backgrounds, I never felt like a minority at Cornell. I was surrounded by diversity and supported in an environment where I could excel.

I have fond memories of the faculty, including Richard White in civil engineering, Subrata Mukherjee in theoretical and applied mechanics, and Steven Strogatz in applied math and computer science. They all opened my aperture, and I realized the diversity and depth of many fields. I loved the beauty of how simple mathematical formulae govern mechanics. I loved how this can be translated into applied mathematics and computer programs. I started connecting more with science and physics at large. And I was extremely fortunate that those professors guided me to discover those depths and breadths.

Cornell was one of the best places in the world to have the mindset of a lifelong learner. I remember being told that it was very hard to do well in certain classes. I simply took such comments from some of my peers as invitations to excel, and I think I did.

Cornell also encouraged my passion for community service. While a student, I volunteered at a school in Lansing, New York, spending hours talking about STEM and the career possibilities. I didn't have a car, so I took a taxi for each visit. On my student stipend, that was expensive. But I was so energized by the promise of influencing future engineers and scientists.

After Cornell, going to GE was a natural fit. GE has a culture of meritocracy that we cherish and value, as well as an emphasis on diversity of thought that we are proud to promote.

With more than 33,000 engines in service, GE is a world leader in jet engine manufacturing and spends $1 billion annually on commercial jet engine research and development.

What is the business case for diversity?

A workforce representative of the population is good for business, but what matters is how an organization harnesses diversity, and creates an environment where all voices are heard. People who come to work as their full selves have more confidence to raise breakthrough ideas, drive their own careers, and bring others along. When people focus energy on the work — as opposed to wasting time and energy pretending to be something they're not — businesses and organizations thrive.

In the U.S., our diversity is a unique advantage. I do a lot of work with the Society for Asian Scientists and Engineers to lift up others in my community.

In your current position, what do you see as the most pressing problems faced by the next generation of engineers?

Sustainability will be a primary focus for all engineers around the globe for decades to come.

The challenges facing the world today are ripe for innovative problem solvers. When engineers come together for a common purpose, it is magical. I have found this to be especially true for aerospace engineers and our team at GE Aviation. If we can harness the power of a diverse group of engineers, we can change the world.

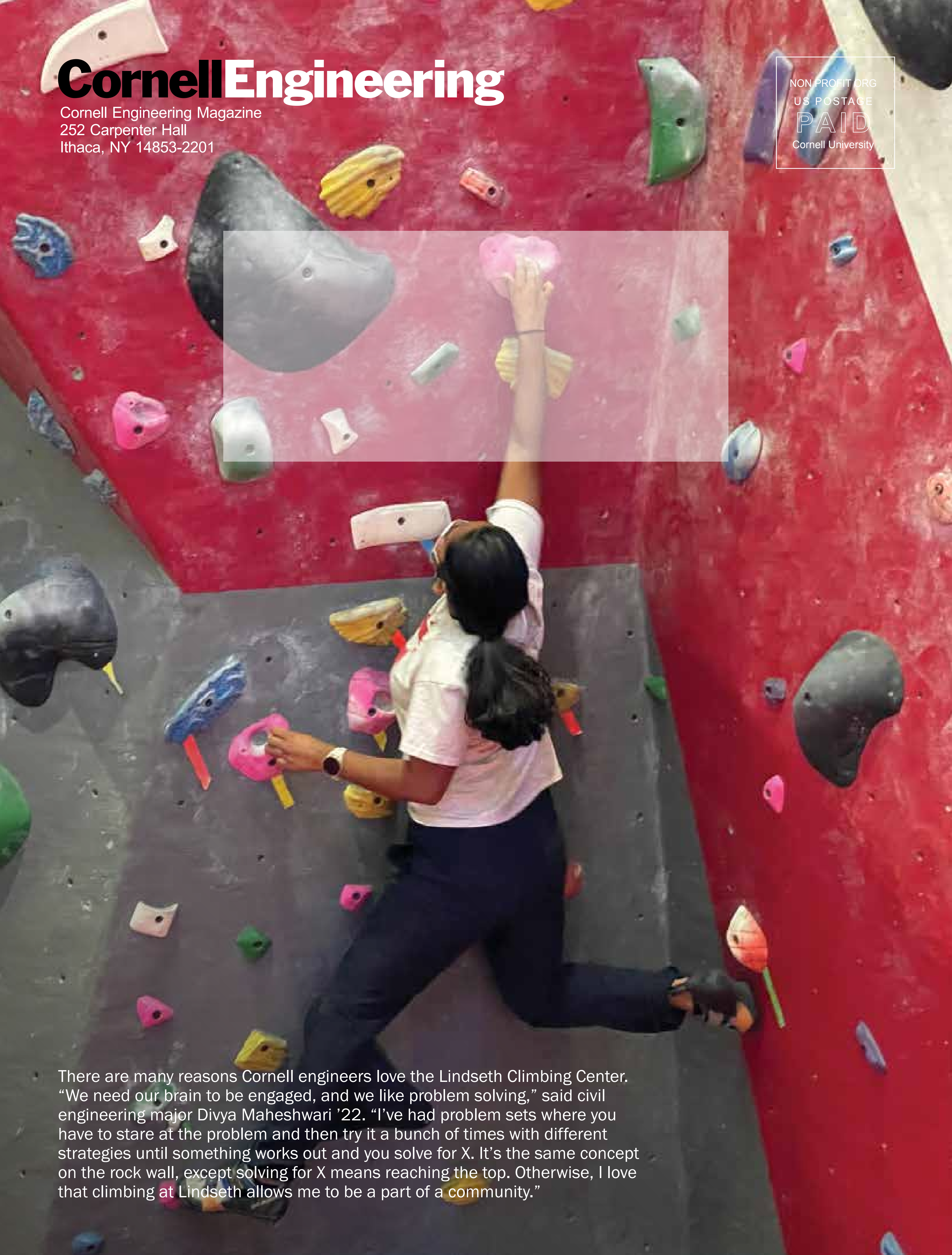
Recently, GE committed to a 10-year, $100 million investment in a program called Next Engineers, which is a college-readiness program focused on increasing the diversity of young people in the engineering field. In some ways, it's an incredible continuation of the work I began at the school in Lansing.

Can you talk about the future of sustainable aviation and the role you intend to play in it?

At GE Aviation, we have thousands of engineers who wake up every day thinking about how to invent the future of flight. We know that the aviation industry is at a pivotal moment. We must reduce carbon emissions to earn the right to grow.

GE and our partner in France, Safran, have had joint engineering teams working together since 2019 to mature and demonstrate open fan, hybrid electric, advanced materials, compact core and other technologies that will help redefine commercial aviation again. We see a future with a more than 20% reduction in fuel consumption for the next single-aisle aircraft engine application by the mid-2030s, compared to today's most fuel-efficient engines. It will also be sustainable aviation fuel ready and hydrogen capable. This is all in a program that we announced earlier this year called RISE, which stands for "Revolutionary Innovations for Sustainable Engines" to accelerate innovations and meet the sustainability goals we as an industry set for ourselves.

This is our North Star — and our responsibility to this planet and our children.



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There are many reasons Cornell engineers love the Lindseth Climbing Center. “We need our brain to be engaged, and we like problem solving,” said civil engineering major Divya Maheshwari ’22. “I’ve had problem sets where you have to stare at the problem and then try it a bunch of times with different strategies until something works out and you solve for X. It’s the same concept on the rock wall, except solving for X means reaching the top. Otherwise, I love that climbing at Lindseth allows me to be a part of a community.”