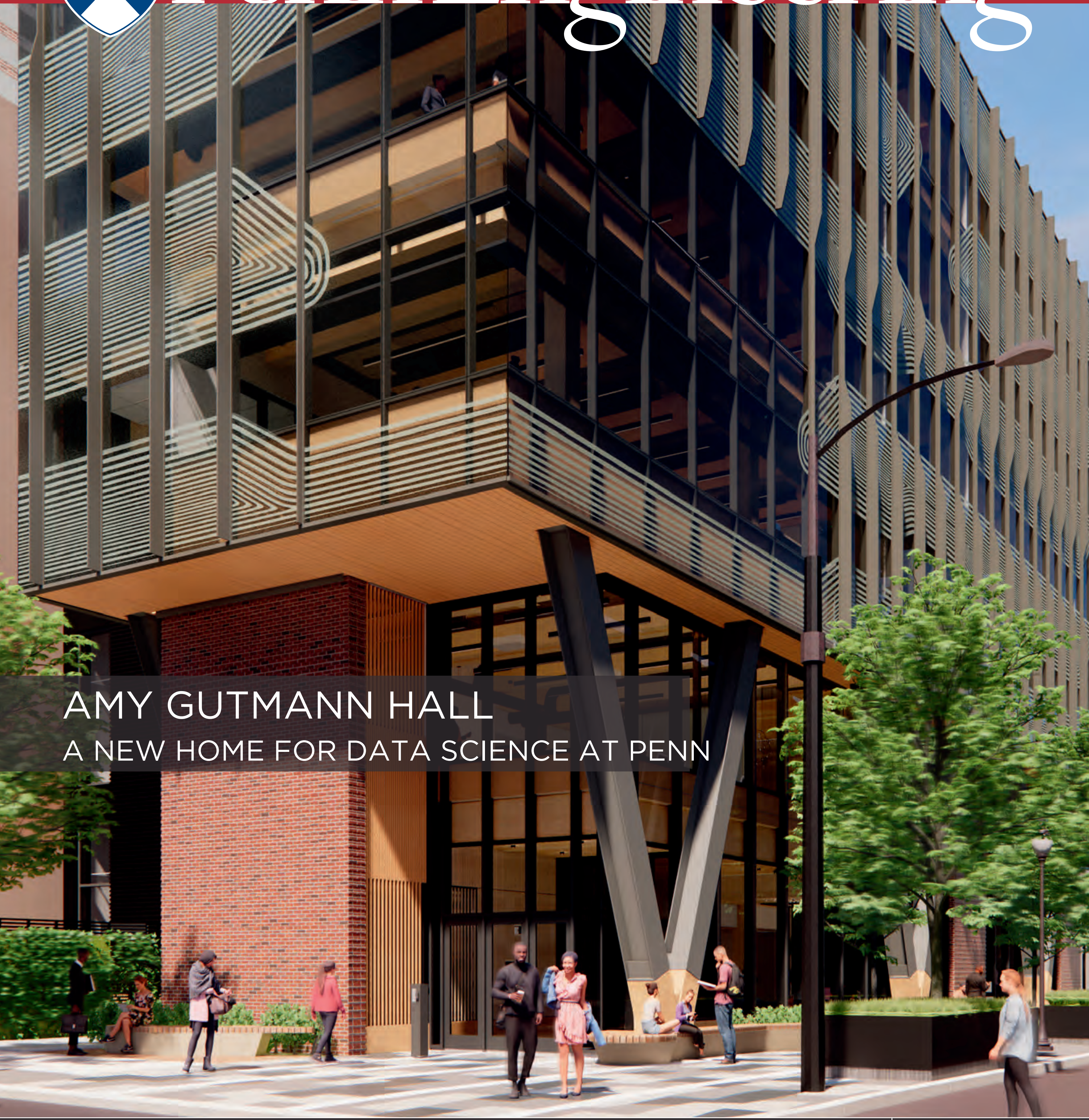
Penn Engineering



AMY GUTMANN HALL

A NEW HOME FOR DATA SCIENCE AT PENN

UNIVERSITY OF PENNSYLVANIA | FALL 2021

Overcoming Obstacles

After 17 months of scaled closures and associated public health measures due to the coronavirus pandemic, this fall Penn Engineering was able to welcome all students back to the Engineering complex with full in-person learning and labs. Innovations as large as the mRNA vaccines and as small as increasing the usability of the complex's existing outdoor spaces have allowed students and faculty to persevere and enjoy the on-campus experiences that were absent over the previous academic year.

This semester, the Quain Courtyard became a bustling hub of collaborative study and socializing, where students could gather outside without masks and grab a bite to eat with friends. After more than a year of social distancing and strict protocols, Penn Engineering's students, faculty and staff are embracing the "new normal" on campus, an integral part of this historic time at Penn.

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University of Pennsylvania
School of Engineering and Applied Science

Amy Gutmann Hall

"THE DATA SCIENCE REVOLUTION IS TRANSFORMING SO MANY ASPECTS OF OUR LIVES, FROM SCIENCE AND DISCOVERY, TO RESEARCH AND DEVELOPMENT, TO TECHNOLOGICAL INNOVATION AND EDUCATION. AMY GUTMANN HALL WILL PROVIDE A VIBRANT ECOSYSTEM FOR DATA SCIENCE AND ENGINEERING THAT WILL BE SURE TO TRANSFORM BOTH PENN AND PHILADELPHIA."

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Essential Engineers

In the time since the last issue of *Penn Engineering* magazine was published (two years ago!) our world has been one of rapid change. The world is still grappling with the pandemic, but I maintain that there has never been a better time to be an engineer at Penn.

Engineers are wired to excel in times such as these. In fact, without engineers and our innovative mindset, the last two years could have been even more dire. Engineers around the world were able to design new PPE, develop new vaccines, create new digital tools for communication and collaboration, rapidly improve supply chains and more.

At Penn Engineering, our scientists were some of the first to return to laboratories on campus to continue the essential research for which there can be no "pause." We engineered face shields and masks well before the supply chain was able to meet the demand, and we developed new COVID-19 tests in early 2020. Our educators quickly pivoted to offer classes fully online, even sending lab kits to students across the world in order to allow them to complete their studies.

Throughout all of this upheaval, the members of the Penn Engineering community have worked tirelessly to keep the trajectory of the School on a course to meet our strategic goals. One of these goals, providing collaborative spaces that position us for leadership in research, is even more within reach as we have broken ground on Amy Gutmann Hall, the new facility that will house data science research and education at Penn.

We are deeply grateful to naming donor Harlan Stone (C'80, PAR'13) for his recognition of President Amy Gutmann's years spent championing the work that we do here at Penn. It is in great part due to the vision of President Gutmann that Penn Engineering continues to be an integral part of the future of the University. The three key tenets of the Penn Compact 2022: Innovation, Inclusion and Impact, are all at the forefront of the mission and planning for our School. It has been gratifying to work for so many years with President Gutmann, who we not only count as an honorary Penn Engineer, but also a key proponent of technological innovation and an indispensable advocate for engineers in our society.

AMY GUTMANN HALL

A NEW HOME FOR DATA SCIENCE AT PENN

By Janelle Weaver

More data is being produced across diverse fields within science, engineering and medicine than ever before, and our ability to collect, store and manipulate it grows by the day. With scientists of all stripes reaping the raw materials of the digital age, there is an increasing focus on developing better strategies and techniques for refining this data into knowledge, and that knowledge into action.

Enter data science, where researchers try to sift through and combine this information to understand relevant phenomena, build or augment models, and make predictions.

One powerful technique in data science's armamentarium is machine learning, a type of artificial intelligence that enables computers to automatically generate insights from data without being explicitly programmed as to which correlations they should attempt to draw.

PENN ACADEMIC PROGRAMS AND RESEARCHERS ON THE LEADING EDGE OF THE DATA SCIENCE FIELD WILL SOON HAVE A NEW PLACE TO CALL HOME: AMY GUTMANN HALL.

Advances in computational power, storage and sharing have enabled machine learning to be more easily and widely applied, but new tools for collecting reams of data from massive, messy and complex systems—from electron microscopes to smart watches—are what have allowed it to turn entire fields on their heads.

"This is where data science comes in," says Susan Davidson, Weiss Professor in Computer and Information Science (CIS) at Penn Engineering. "In contrast to fields where we have well-defined models, like in physics, where we have Newton's laws and the theory of relativity, the goal of data science is to make predictions where we don't have good models: a data-first approach using machine learning rather than using simulation."

Penn Engineering's formal data science efforts include the establishment of the Warren Center for Network & Data Sciences, which brings together researchers from across Penn with the goal of fostering research and innovation in interconnected social, economic and technological systems. Other research communities, including Penn Research in Machine Learning and the student-run Penn Data Science Group, bridge the gap between schools, as well as between industry and academia. Programmatic opportunities for Penn students include a Data Science minor for undergraduates, and a Master of Science in Engineering in Data Science, which is directed by Davidson and jointly administered by CIS and Electrical and Systems Engineering.

Penn academic programs and researchers on the leading edge of the data science field will soon have a new place to call home: Amy Gutmann Hall. The 116,000-square-foot, six-floor building, located on the northeast corner of 34th and Chestnut Streets near Lauder College House, will centralize resources for researchers and scholars across Penn's 12 schools and numerous academic centers while making the tools of data analysis more accessible to the entire Penn community.

Faculty from all six departments in Penn Engineering are at the forefront of developing innovative data science solutions, primarily relying on machine learning, to tackle a wide range of challenges. In the pages that follow, Penn Engineering researchers show how they use data science in their work to answer fundamental questions in topics as diverse as genetics, "information pollution," medical imaging, nanoscale microscopy, materials design and the spread of infectious diseases.

Amy Gutmann Hall, a 116,000-square-foot, six-floor building, will centralize resources for researchers and scholars across Penn while making the tools of data analysis more accessible to the entire community.

JENNIFER PHILLIPS-CREMINS

Unraveling the 3D Genomic Code

QUESTION

WHEN SOME DNA SEQUENCES REPEAT THEMSELVES, NOTHING MUCH HAPPENS. SO WHY DO OTHER REPEATS LEAD TO SERIOUS NEUROLOGICAL DISORDERS?

DATA

WHICH GENES CONTACT ONE ANOTHER IN 3D WHEN THE GENOME IS TIGHTLY FOLDED UP IN THE CELL.

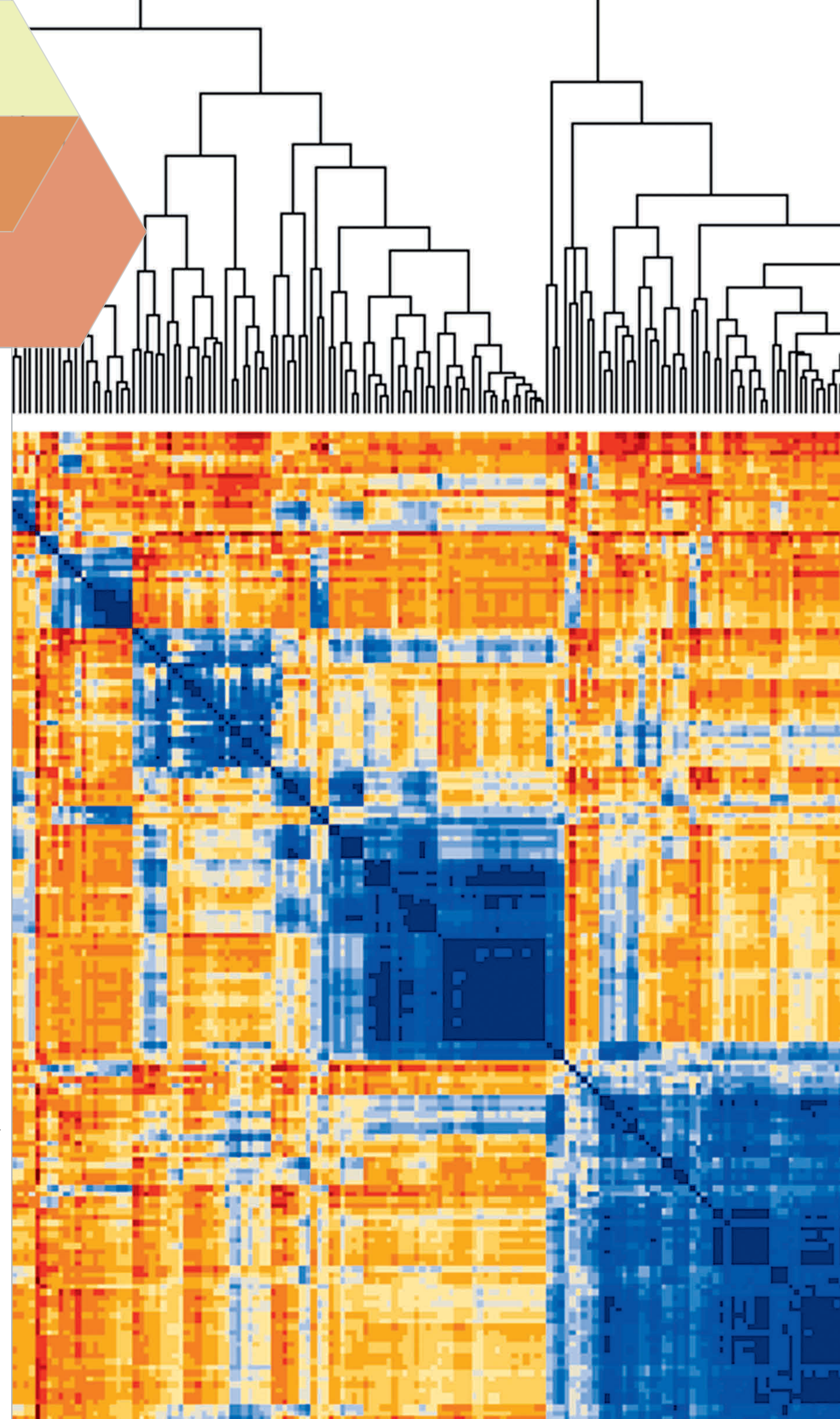
KNOWLEDGE

THE DNA REPEATS THAT LEAD TO A GROUP OF NEUROLOGICAL DISORDERS ARE ALL AT THE BOUNDARIES OF A SPECIFIC UNIQUE 3D GENOME-FOLDING PATTERN.

ACTION

UNDERSTANDING THE SIGNIFICANCE OF THE RELATIONSHIP BETWEEN DNA REPEATS AND THE 3D GENOME, SUCH AS IF FOLDING PATTERNS ARE DISRUPTED WHEN REPEATS EXPAND, COULD LEAD TO TREATMENTS FOR THIS CLASS OF DISEASES.

"In our group, we use an integrated, interdisciplinary approach relying on cutting-edge computational and molecular technologies to uncover biologically meaningful patterns in large data sets."



Heatmaps visualize which physically distant genes are brought into contact when the genome is in its folded state.

Scattered throughout the genomes of healthy people are tens of thousands of repetitive DNA sequences called short tandem repeats (STRs). But the unstable expansion of these repetitions is at the root of dozens of inherited disorders, including Fragile X syndrome, Huntington's disease and ALS. Why these STRs are susceptible to this disease-causing expansion, whereas most remain relatively stable, remains a major conundrum.

Complicating this effort is the fact that disease-associated STR tracts exhibit tremendous diversity in sequence, length and localization in the genome. Moreover, that localization has a three-dimensional element because of how the genome is folded within the nucleus. Mammalian genomes are organized into a hierarchy of structures called topologically associated domains (TADs). Each one spans millions of nucleotides and contains smaller subTADs, which are separated by linker regions called boundaries.

"The genetic code is made up of three billion base pairs. Stretched out end to end, it is 6 feet 5 inches long, and must be subsequently folded into a nucleus that is roughly the size of a head of a pin," says Jennifer Phillips-Cremins, Associate Professor and Dean's Faculty Fellow in Bioengineering. "Genome folding is an exciting problem for engineers to study because it is a problem of big data. We not only need to look for patterns along the axis of three billion base pairs of letters, but also along the axis of how the letters are folded into higher-order structures."

To address this challenge, Phillips-Cremins and her team recently developed a new mathematical approach called 3DNetMod to accurately detect these chromatin domains in 3D maps of the genome in collaboration with the lab of Dani Bassett, J. Peter Skirkanich Professor in Bioengineering.

"In our group, we use an integrated, interdisciplinary approach relying on cutting-edge computational and molecular technologies to uncover biologically meaningful patterns in large data sets," Phillips-Cremins says. "Our approach has enabled us to find patterns in data that classic biology training might overlook."

In a recent study, Phillips-Cremins and her team used 3DNetMod to identify tens of thousands of subTADs in human brain tissue. They found that nearly all disease-associated STRs are located at boundaries demarcating 3D chromatin domains. Additional analyses of cells and brain tissue from patients with Fragile X syndrome revealed severe boundary disruption at a specific disease-associated STR.

"To our knowledge, these findings represent the first report of a possible link between STR instability and the mammalian genome's 3D folding patterns," Phillips-Cremins says. "The knowledge gained may shed new light into how genome structure governs function across development and during the onset and progression of disease. Ultimately, this information could be used to create molecular tools to engineer the 3D genome to control repeat instability."

ROB RIGGLEMAN

Predicting Where Cracks Will Form

QUESTION

WHY DO SOME PLASTICS DENT AND BEND UNDER STRESS, WHILE OTHERS SNAP, BREAK OR SHATTER?

DATA

DOZENS OF SIMULATIONS, EACH GENERATING HUNDREDS OF FRAMES OF POSITIONAL COORDINATES OF APPROXIMATELY 100,000 DIGITAL ATOMS.

KNOWLEDGE

CLUSTERS OF 10–50 ATOMS CAN PREDICT HOW AND WHERE A MATERIAL BEGINS TO FAIL.

ACTION

UNDERSTANDING THE PROPERTIES OF THESE CLUSTERS GIVES FUNDAMENTAL INSIGHT INTO MATERIAL WEAKNESS AND WAYS TO DESIGN AROUND IT.

Unlike crystals, disordered solids are made up of particles that are not arranged in a regular way. Despite their name, disordered solids have many desirable properties: Their strength, stiffness, smooth surfaces and corrosion resistance make them suitable for a variety of applications, ranging from semiconductor manufacturing to eyeglass lenses.

But their widespread use is limited because they can be very brittle and prone to catastrophic failure. In many cases, the failure process starts with small rearrangements of the material's component atoms or particles. But without an ordered template to compare to, the structural fingerprints of these rearrangements are subtle.

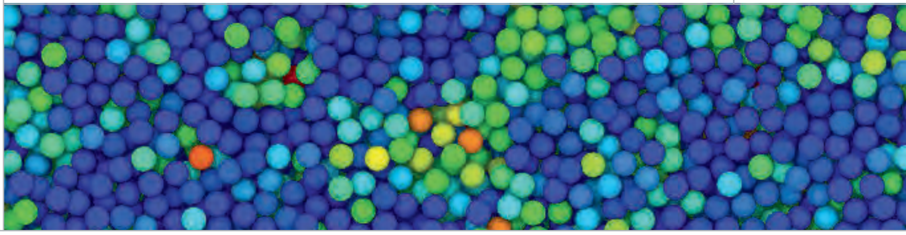
"In contrast to crystalline solids, which are often very tough and ductile—they can be bent a lot without breaking, like a metal spoon—we don't understand how and why nearly all disordered solids are so brittle," says Rob Riggleman, Associate Professor in Chemical and Biomolecular Engineering. "In particular, identifying those particles that are more likely to rearrange prior to deforming the material has been a challenge."

To address this gap in knowledge, Riggleman and his team use machine learning methods developed by collaborators at Penn along with molecular modeling, which allow them to examine in an unbiased fashion a broad array of structural features, identifying those that may contribute to material failure.

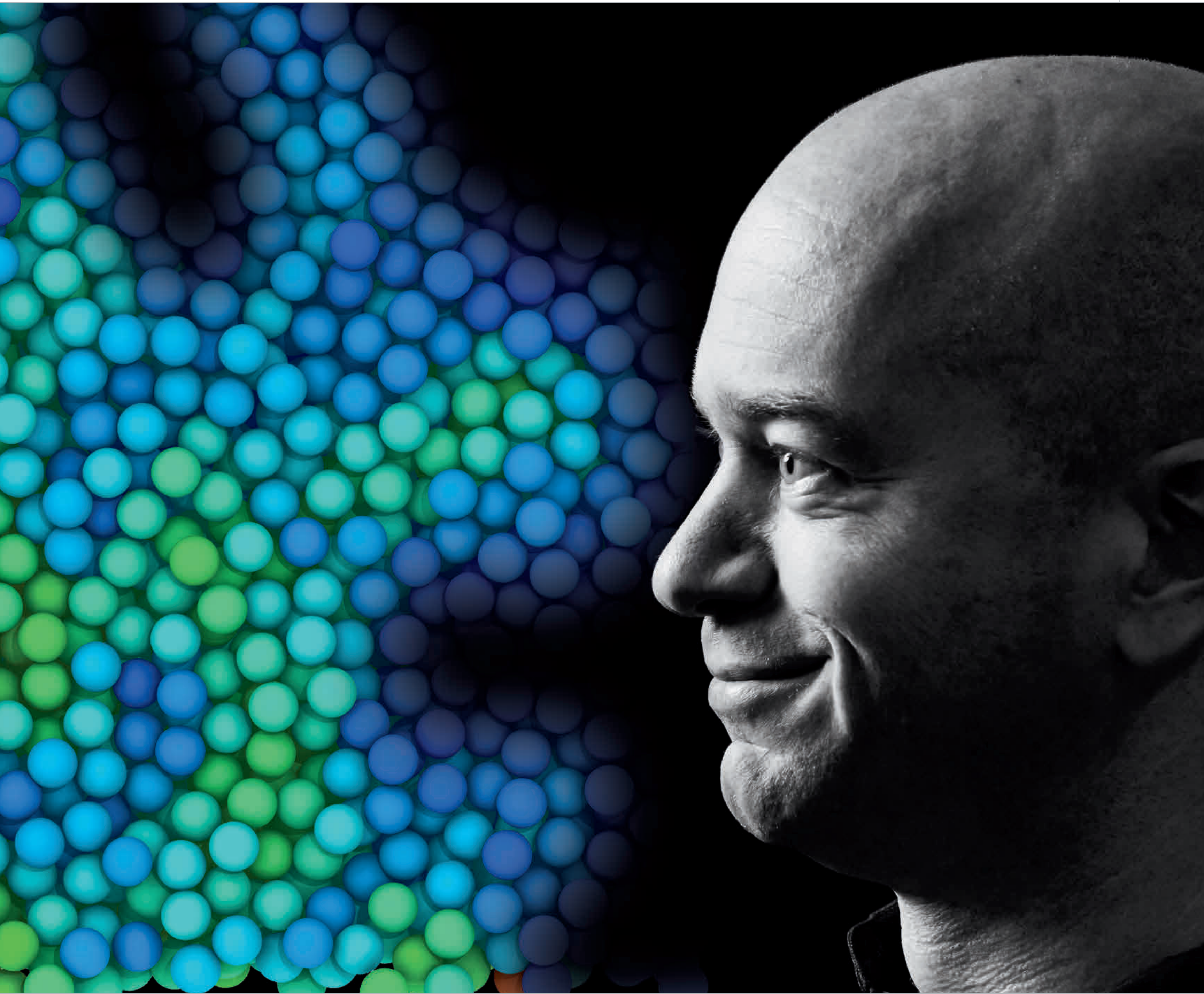
"We find machine learning and data science approaches valuable when our intuition fails us. If we can generate enough data, we can let the algorithms filter and inform us on which aspects of the data are important," Riggleman says. "Our approach is unique because it lets us take a tremendously challenging problem, such as determining in a random-looking, disordered solid, which sections of the material are more likely to fail, and systematically approach the problem in a way that allows physical insight."

Recently, this approach revealed that softness, quantified on a microscopic structural level, strongly predicts particle rearrangements in disordered solids. Based on this finding, the researchers conducted additional experiments and simulations on a range of disordered materials that were strained to failure. Surprisingly, they found that the initial distribution of soft particles in nanoscale materials did not predict where cracks would form. Instead, small surface defects dictated where the sample would fail. These results suggest that focusing on manufacturing processes that lead to smooth surfaces, as opposed to hard interiors, will yield stronger nanoscale materials.

Moving forward, Riggleman and his team plan to use this information to design new materials that are tougher and less prone to breaking. One potential application is to find greener alternatives to concrete that still have the structural properties that have made it ubiquitous. "The synthesis of concrete releases a large amount of CO_2," Riggleman says. "With the global need for housing growing so quickly, construction materials that release less CO_2 could have a big impact on decreasing overall carbon emissions."



"We find machine learning and data science approaches valuable when our intuition fails us. If we can generate enough data, we can let the algorithms filter and inform us on which aspects of the data are important."



Molecular models provide a data-driven view into the structure of disordered materials, as the position of their individual atoms or particles can't be predicted by their chemical makeup alone. Such simulations give researchers access to machine learning tools, which can be used to find commonalities that lead to brittleness in these materials.

DAN ROTH

Navigating Information Pollution

QUESTION

WITH AN EVER-INCREASING NUMBER OF MEDIA OUTLETS, HOW CAN PEOPLE ASSESS WHETHER THE INFORMATION THEY'RE READING IS TRUSTWORTHY?

DATA

TEXT CULLED FROM HUNDREDS OF THOUSANDS OF NEWS ARTICLES, WEBSITES AND SOCIAL MEDIA POSTS.

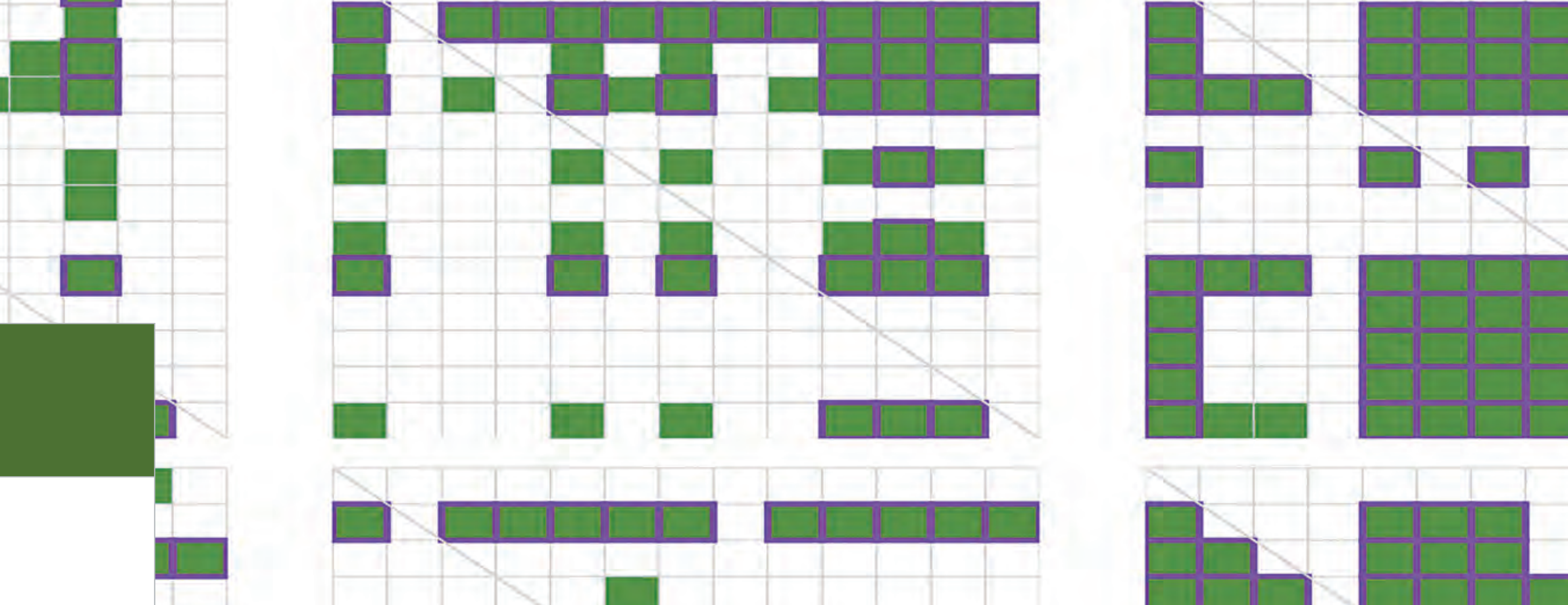
KNOWLEDGE

CROSS-REFERENCED WITH LANGUAGE FROM KNOWN TRUSTWORTHY SOURCES, ALGORITHMS CAN VERIFY WHETHER A CLAIM MADE IN A NEWS ARTICLE IS SUPPORTED BY TRUSTWORTHY EVIDENCE.

ACTION

INFORMATION CAN BE ORGANIZED BASED ON THE STANCE IT HAS RELATIVE TO VARIOUS CLAIMS, AND AUGMENTED WITH EVIDENCE AND LEVEL OF TRUSTWORTHINESS.

"Our framework develops machine learning and natural language understanding tools that identify a spectrum of perspectives relative to a claim, each with evidence supporting it."



Natural language processing allows for large-scale analysis of text; natural language understanding adds a semantic layer, attempting to give machines the ability to comprehend the meaning of text as a human would.

One unfortunate consequence of the information revolution has been information contamination. These days, it can be very difficult to establish what is really known, thanks to the emergence of social networks and news aggregators, combined with ill-informed posts, deliberate efforts to create and spread sensationalized information, and strongly polarized environments. "Information pollution," or the contamination of the information supply with irrelevant, redundant, unsolicited, incorrect and otherwise low-value information, is a problem with far-reaching implications.

"In an era where generating content and publishing it is so easy, we are bombarded with information and are exposed to all kinds of claims, some of which do not always rank high on the truth scale," says Dan Roth, Eduardo D. Glandt Distinguished Professor in Computer and Information Science. "Perhaps the most evident negative effect is the propagation of false information in social networks, leading to destabilization and loss of public trust in the news media. This goes far beyond politics. Information pollution exists in the medical domain, education, science, public policy and many other areas."

According to Roth, the practice of fact-checking won't suffice to eliminate biases. Understanding most nontrivial claims or controversial issues requires insights from various perspectives. At the heart of this task is the challenge of equipping computers with natural language understanding, a branch of artificial intelligence that deals with machine comprehension of language. "Rather than considering a claim as being true or false, one needs to view a claim from a diverse yet comprehensive set of perspectives," Roth says. "Our framework develops machine learning and natural language understanding tools that identify a spectrum of perspectives relative to a claim, each with evidence supporting it."

Along with identifying perspectives and evidence for them, Roth's group is working on a family of probabilistic models that jointly estimate the trustworthiness of sources and the credibility of claims they assert. They consider two scenarios: one in which information sources directly assert claims, and a more realistic and challenging one in which claims are inferred from documents written by sources.

The goals are to identify sources of perspectives and evidence and characterize their level of expertise and trustworthiness based on past record and consistency with other held perspectives. They also aim to understand where the claim may come from and how it has evolved.

"Our research will bring public awareness to the availability of solutions to information pollution," Roth said. "At a lower level, our technical approach would help identify the spectrum of perspectives that could exist around topics of public interest, identify relevant expertise and thus improve public access to diverse and trustworthy information."

VICTOR PRECIADO

Controlling the Spread of Epidemics

QUESTION

WE CAN MAKE PREDICTIONS FOR SYSTEMS THAT ARE BASED ON THE LAWS OF PHYSICS. BUT WHAT ABOUT THOSE WITHOUT WELL-DEFINED MODELS, LIKE A PANDEMIC SPREADING OVER A HUMAN CONTACT NETWORK?

DATA

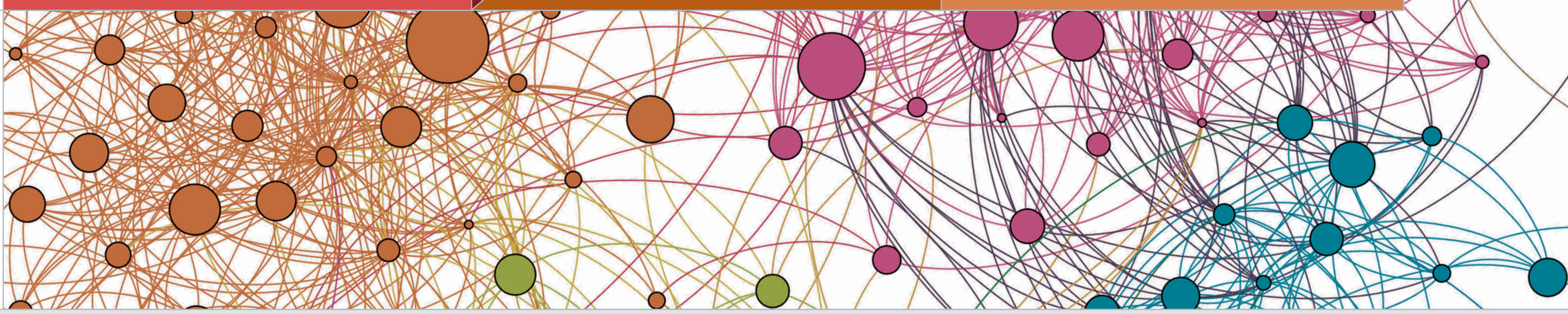
MORTALITY STATISTICS FROM PREVIOUS OUTBREAKS, INCLUDING WHEN AND WHERE INFECTIONS OCCURRED.

KNOWLEDGE

UNDERSTANDING THE OVERARCHING PATTERNS AND MECHANISMS OF THE PROPAGATION OF A DISEASE THROUGHOUT A POPULATION.

ACTION

BY DERIVING THESE PATTERNS FROM REAL-LIFE EXAMPLES, DATA-DRIVEN MODELS THAT HELP EPIDEMIOLOGISTS DESIGN EFFECTIVE STRATEGIES TO CONTAIN THE SPREAD OF A DISEASE CAN BE BUILT.



The number and density of nodes and edges in a social network has a direct link to its properties, such as how quickly a virus within it can spread.

The emergence of COVID-19, along with recent epidemics such as the H1N1 influenza, the Ebola outbreak, and the Zika crisis, underscore that the threat of infectious diseases to human populations is very real.

“Accurate prediction and cost-effective containment of epidemics in human and animal populations are fundamental problems in mathematical epidemiology,” says Victor Preciado, Associate Professor and Graduate Chair of Electrical and Systems Engineering. “In order to achieve these goals, it is indispensable to develop effective mathematical models describing the spread of disease in human and animal contact networks.”

Even though epidemic models have existed for centuries, they need to be continuously refined to keep up with the variables of a more densely interconnected world. Toward this goal, engineers like Preciado have recently started tackling the problem using innovative mathematical and computational approaches to model and control complex networks.

Using these approaches, Preciado and his team have computed the cost-optimal distribution of resources such as vaccines and treatments throughout the nodes in a network to achieve the highest level of containment. These models can account for varying budgets, differences in individual susceptibility to infection and different levels of available resources to achieve more realistic results. The researchers illustrated their approach by designing an optimal protection strategy for a real air transportation network faced with a hypothetical worldwide pandemic.

Moving forward, Preciado and his team hope to develop an integrated framework for modeling, prediction and control of epidemic outbreaks using finite resources and unreliable data. Although public health agencies collect and report relevant field data, that data can be incomplete and coarse-grained. In addition, these agencies are faced with the challenge of deciding how to allocate costly, scarce resources to efficiently contain the spread of infectious diseases.

“Accurate prediction and cost-effective containment of epidemics in human and animal populations are fundamental problems in mathematical epidemiology.”

“Public health agencies can greatly benefit from information technologies to filter and analyze field data in order to make reliable predictions about the future spread of a disease,” Preciado says. “But in order to implement practical disease-management tools, it is necessary to first develop mathematical models that can replicate salient geo-temporal features of disease transmission.”

Ultimately, Preciado’s goal is to develop open-source infection management software, freely available to the research community, to assist health agencies in the design of practical disease-containment strategies.

“This could greatly improve our ability to efficiently detect and appropriately react to future epidemic outbreaks that require a rapid response,” Preciado says. “In addition, modeling spreading processes in networks could shed light on a wide range of scenarios, including the adoption of an idea or rumor through a social network like Twitter, the consumption of a new product in a marketplace, the risk of receiving a computer virus, the dynamics of brain activity, and cascading failures in the electrical grid.”

ERIC STACH

Understanding Why Catalysts Degrade

QUESTION

WHAT IS HAPPENING ON THE SURFACES OF CATALYSTS, LIKE THE ONES THAT ENABLE THE CHEMICAL REACTIONS IN HYDROGEN FUEL CELLS, SUCH THAT THEY STOP WORKING OVER TIME?

DATA

TERABYTES OF HIGH-RESOLUTION IMAGES AND SPECTRA TAKEN OF CATALYSTS BY ELECTRON MICROSCOPES.

KNOWLEDGE

HOW, WHERE AND WHEN NANOPARTICLES REARRANGE DURING THE CHEMICAL REACTIONS THEY CATALYZE.

ACTION

USING MACHINE LEARNING, RATHER THAN HAND-ANNOTATING INDIVIDUAL IMAGES, RESEARCHERS CAN FIND THE MATERIAL PROPERTIES THAT ARE KEY TO MORE STABLE, LONGER-LASTING SYSTEMS.

"By gathering streams of rich data, we can now track individual coarsening events, and from this, learn the basic physics of the process and thereby create strategies to prevent this process from occurring."

The presence of a metal catalyst is often necessary for certain chemical reactions to take place, but those metals can be rare and expensive. Shrinking these metals down to nanoparticles increases their ratio of surface area to volume, reducing the overall amount of metal required to catalyze the reaction.

However, metal nanoparticles are unstable. A process called "coarsening" causes them to spontaneously grow by bonding with other metal atoms in their environment. Though the exact mechanism by which coarsening occurs is unknown, the loss of nanoparticles' surface area advantage has clear consequences, such as the irreversible degradation in the performance of several important systems, including automotive catalytic converters and solid oxide fuel cells.

"This process is bad, as it decreases the efficiency of the catalysts overall, adding significant cost and leading to efficiency losses," says Eric Stach, Professor in Materials Science and Engineering and Director of the Laboratory for Research on the Structure of Matter (LRSM). "By gathering streams of rich data, we can now track individual events, and from this, learn the basic physics of the process and thereby create strategies to prevent this process from occurring."

The Stach lab uses *in situ* and *operando* microscopy techniques, meaning it collects data from materials in their native environments and as they function. Advances in electron microscopy techniques have increasingly shed light on how materials react under the conditions in which they are designed to perform; *in situ* electron microscopy experiments can produce hundreds of high-resolution images per second.

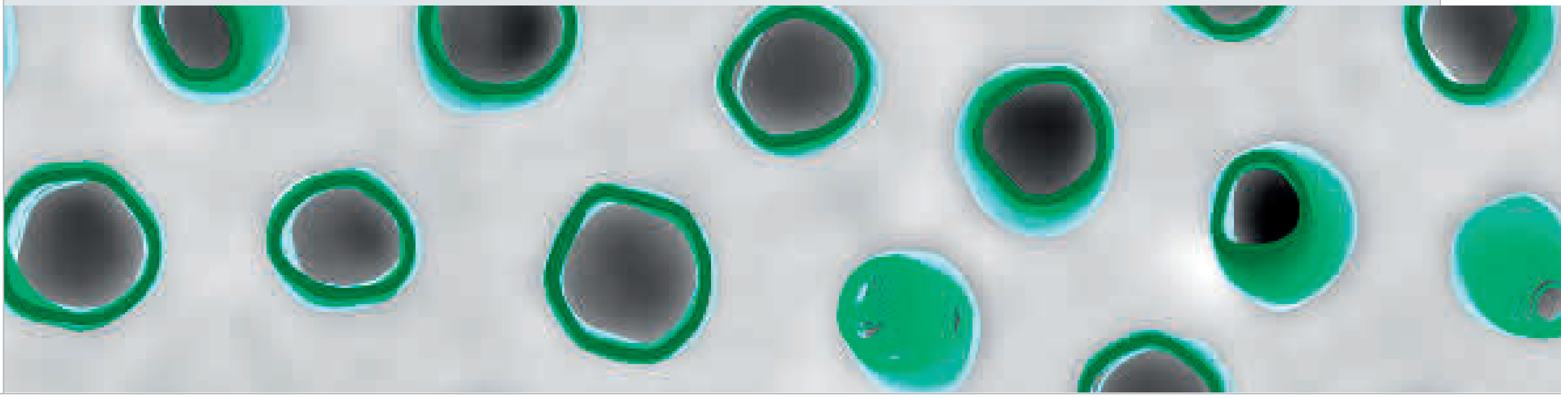
"It is possible for us to gather up to four terabytes in just 15 minutes of work. This is the result of new capabilities for detecting electrons more efficiently," Stach explains. "But this is so much data that we cannot process it by hand. We have been increasingly utilizing data science tools developed by others in more directly related fields to automate our analysis of these images."

In particular, Stach and his team have applied neural network models to transmission electron microscopy images of metal nanoparticles. The use of neural networks allows for the learning of complex features that are difficult to represent manually and interpret intuitively. Using this approach, the researchers can efficiently measure and track particles frame to frame, gaining insight into fundamental processes governing coarsening in industrial catalysts at the atomic scale.

The next step for the researchers will be to compare the high-resolution image analyses to computational models, thereby shedding light on the underlying physical mechanisms. In the end, understanding the processes by which these metallic particles coarsen into larger structures may lead to the development of new materials for electronic devices, solar energy and batteries.

"The development of new materials drives nearly all of modern technology," Stach says. "Materials characterization such as what we are doing is critical to understanding how different ways of making new materials lead to properties that we desire."

Precisely tracking the size and shape of nanoparticles as they coarsen is made possible by computational approaches that can automatically detect those changes from a series of microscopy images.



PARIS PERDIKARIS

Developing Digital Twins

QUESTION

EVEN THE MOST ADVANCED HEALTHCARE IMAGING TECHNOLOGIES OFTEN CAN'T DIRECTLY MEASURE THE MOST CLINICALLY RELEVANT VARIABLES, SUCH AS BLOOD PRESSURE. HOW CAN WE BRIDGE THIS GAP?

DATA

PHYSICS-BASED DIGITAL MODELS OF PHYSIOLOGICAL SYSTEMS, SUCH AS THE HEART, COMBINED WITH BIOMETRICS TAKEN FROM INDIVIDUAL PATIENTS.

KNOWLEDGE

MACHINE LEARNING PROVIDES STATISTICAL CORRELATIONS BETWEEN THE VARIABLES WE CAN MEASURE AND THE VARIABLES WE WANT TO PREDICT, ENABLING A MODEL KNOWN AS A "DIGITAL TWIN."

ACTION

DIGITAL TWINS CAN PROVIDE AN AVENUE FOR SIMULATING THE RISK AND EFFECTIVENESS OF PERSONALIZED MEDICAL TREATMENTS.

Using powerful magnets and software, a 4D flow MRI can provide a detailed and dynamic look at a patient's vascular anatomy and blood flow. Yet this high-tech device is no match for a $20 sphygmometer when it comes to measuring one of the most critical variables for heart disease and stroke: blood pressure. Although digital models could be used to predict blood pressure from these high-tech scans, they still have not made their way into clinical practice, primarily due to their high computational cost and noisy data.

To address this problem, Paris Perdikaris, Assistant Professor in Mechanical Engineering and Applied Mechanics, and his collaborators recently developed a machine learning framework that could enable these sorts of predictions to be made in an instant.

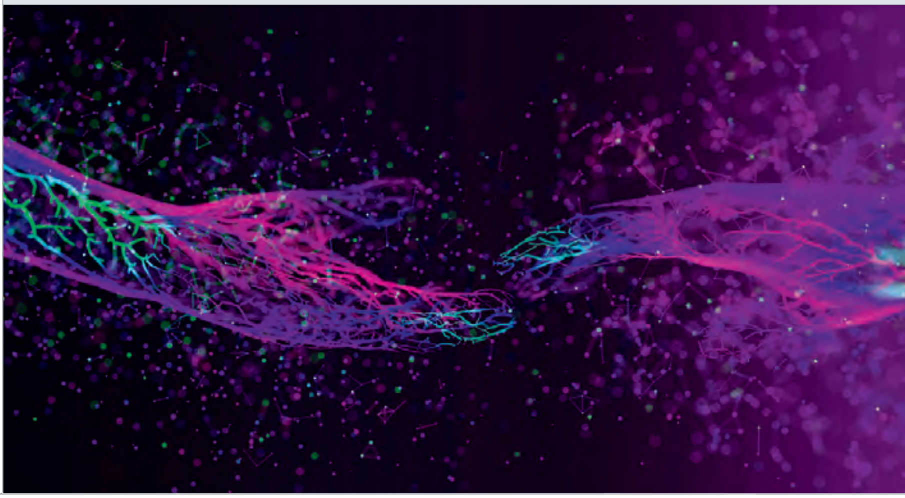
By capturing the underlying physics at play in the circulatory system, for example, a relatively small number of biometric data points collected from a patient could be extrapolated out into a wealth of other vital statistics. This more comprehensive simulation of a patient, nicknamed a "digital twin," would give a multidimensional view of their biology and allow clinicians and researchers to virtually test treatment strategies.

"Integrating machine learning and multiscale modeling through the creation of virtual replicas of ourselves can have a significant impact in the biological, biomedical and behavioral sciences," Perdikaris says. "Our efforts on digital twins aspire to advance healthcare by delivering faster, safer, personalized and more efficient diagnostics and treatment procedures to patients."

Perdikaris's team recently published a study showing how this framework, known as "Physics-Informed Deep Operator Networks" can be used to find the relationship between the inputs and outputs of complex systems defined by a certain class of mathematical equations.

Other machine learning systems can discover these relationships, but only through brute force. They might require data from tens of thousands of patients to be properly calibrated, and then would still require significant computational time to calculate the desired outputs from a new patient's input.

No one type of medical imaging can capture every relevant piece of information about a patient at once. Digital twins or multiscale, physics-based simulations of biological systems, would allow clinicians to accurately infer more vital statistics from fewer data points.



"Integrating machine learning and multiscale modeling through the creation of virtual replicas of ourselves called 'digital twins' can have a massive impact in the biological, biomedical and behavioral sciences."

Physics-Informed Deep Operator Networks can tackle this problem in a more fundamental way: One designed to predict blood pressure from blood velocity measured at a specific point in the circulatory system, for example, would essentially learn the underlying laws of physics that govern that relationship. Armed with that knowledge and other relevant variables for a given patient, the system can quickly calculate the desired value based on those fundamental principles.

Moving forward, Perdikaris and his team plan to apply their computational tools to develop digital twins for the human heart, and for blood circulation in placental arteries to elucidate the origins of hypertensive disorders in pregnant women. "Creating digital twins can provide new insights into disease mechanisms, help identify new targets and treatment strategies, and inform decision-making for the benefit of human health," Perdikaris says.

Sophie Bowe

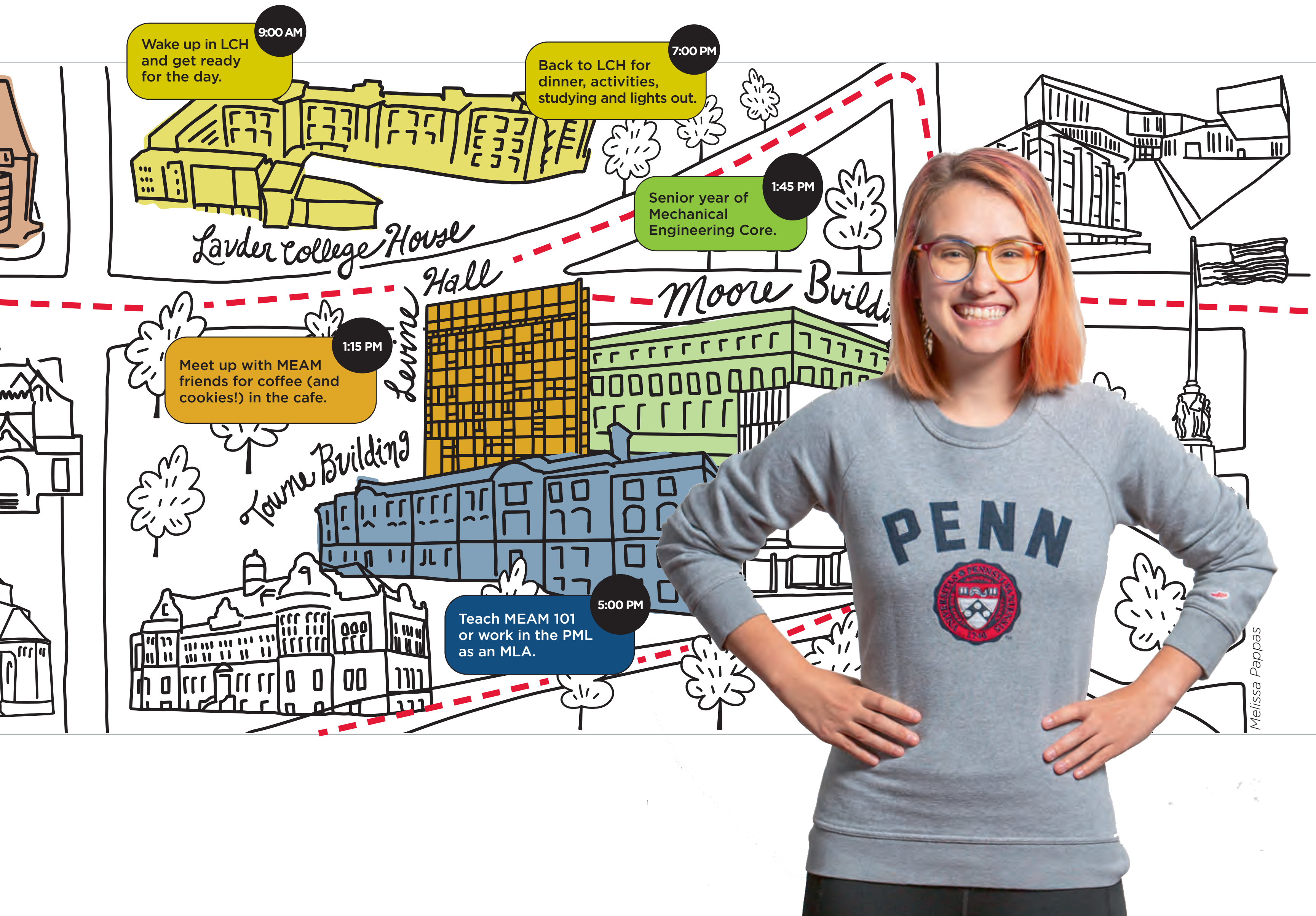
A DAY IN THE LIFE OF A PENN ENGINEER

It was an epiphany experienced while riding on Animal Kingdom's Expedition Everest that granted Sophie Bowe her entrance into the world of engineering. A true believer (until then at least) in the pure magic of Disney theme park attractions, Bowe's "Aha!" moment revealed to her the unseen technological and mechanical underpinnings of the ride. Like so many other engineers-to-be, the 10-year-old Bowe wondered, "Wait. How does this all actually work?" Her father, a mechanical engineer sitting beside her at the time, clearly remembers the moment, and was not at all surprised by the many questions that followed. Her journey of discovery had begun.

Flash-forward to Bowe's arrival at Penn Engineering from the small Midwestern city of Alliance, Ohio. Culture shock? Yes, but in a good way. Bowe found the campus exciting, and the people she met to be kind and welcoming. She delighted in being able to get around Philadelphia on her own power rather than having to drive everywhere. Now, as a senior and a Resident Assistant at Lauder College House, Bowe organizes urban excursions designed to orient and amuse incoming Penn students.

When searching for the right academic fit for her interests and aspirations, Bowe jokes that she had changed her major even before declaring it. Always one to get her hands dirty and figure it out, she found her intellectual home in Mechanical Engineering and Applied Mechanics (MEAM). Bowe's love of making things found full expression in MEAM 101, Introduction to Mechanical Design, and her longtime dream of becoming an "Imagineer" came into even sharper focus.

Now a Teaching Assistant (TA) for that very course and a Machining Laboratory Assistant (MLA) in the Precision Machining Laboratory, Bowe is, quite literally, honing her own skills while helping others. Senior Lecturer Dustyn Roberts, who teaches MEAM



Melissa Pappas

101, describes Bowe as "a natural leader among her peers," and expressed what might be the ultimate vote of confidence in her abilities: Roberts would "ride on anything she designs as an Imagineer, for sure!"

As a MEAM major with a Mathematics minor, Bowe might be stereotyped as "left-brain dominant." But while her toolkit contains the skills necessary for analysis and methodology, her superpower is her openness to magical thinking. A passion for the theater and an appreciation for art both speak to her more creative energies. In her STEM-centered senior year in an accelerated master's program, Bowe looks forward to a sculpture studio course to bring balance to her schedule.

However true, it is almost an understatement to sum up the semesters at Penn during COVID-19 as a "university experience like no other." Bowe looks on the bright side: Having always preferred to study alone, she found that she enjoyed the company of others during Zoom homework sessions, making new friends and strengthening ties with old ones. Closeness with family was also sustaining. Sitting around a bonfire enjoying meals and conversation became a tradition that will undoubtedly remain in the Bowe Family collective memory. With her curiosity given full rein in a comparatively unstructured academic environment, Bowe watched YouTube videos about carpentry and other trade techniques. Perhaps reflecting the unpredictability of the times, Bowe boldly cut off her long hair, coloring it purple, just because.

Bowe is glad to be back on campus for her senior year. Her overarching career goal is "to make people happy" by providing them with magic, fantasy and fun through "Imagineering." Who among us might someday experience the results of her dream?

By Patricia Hutchings

Celebrating
The Power of Penn Engineering

Penn Engineering is celebrating the most successful fundraising campaign in its history. *The Power of Penn Engineering: Inventing the Future*, which ended in June, raised a remarkable $250.3 million in gifts, setting a new philanthropic milestone. More than 7,200 alumni, parents and friends united in exceeding the School's ambitious goal to raise $170 million. "This campaign challenged all of us to envision and invent the future of Penn Engineering," states Nemirovsky Family Dean Vijay Kumar. "The collective power and generosity of our diverse community is propelling Penn Engineering to even greater heights."

UNDERGRADUATE FINANCIAL AID

ORIGINAL GOAL $32 MILLION

TOTAL $36.6 MILLION

CAPITAL PROJECTS

ORIGINAL GOAL $35 MILLION

TOTAL $84.1 MILLION

Gifts to build the next generation of learning and research space are already poised to expand and transform the Penn Engineering campus. The most notable example is the Data Science Building, which will be named Amy Gutmann Hall. Realized through a historic $25 million lead gift from Harlan M. Stone (C'80, PAR'13), the building will enable students and scholars from across Penn and beyond to translate data into knowledge that advances our understanding of the world. Contributions in support of the Data Science Building totaled $79 million, with leadership gifts to name the building's core Data Science Hub and establish powerhouse, interdisciplinary research centers in medical diagnostics, human perception and cybersecurity. Campaign funds also cemented the University's future as an intellectual trailblazer in energy science. The new Vagelos Laboratory for Energy Research and Technology, a joint project spearheaded by Penn Arts and Sciences and Penn Engineering, will play a critical role in Penn's multifaceted commitment to creating a secure energy future.

To increase expertise in these and other rapidly growing fields, Dean Kumar made faculty expansion an overarching priority in his strategic plans for the School. Over the span of the campaign, he oversaw a 25 percent increase in tenure-track faculty, bolstered by over $35 million in donations. Efforts to hire and develop this eminent talent were greatly aided by 22 new endowed positions, surpassing the original goal of 20. These commitments were among the most impactful contributions of the campaign. Many donors were motivated, in part, by the outpouring of support to create six endowed faculty positions in honor of Eduardo Glandt, Dean Emeritus and Professor Emeritus in the Department of Chemical and Biomolecular Engineering. Another significant accomplishment was that faculty across all Penn Engineering

ENDOWED FACULTY SUPPORT

ORIGINAL GOAL $33 MILLION

TOTAL $35.8 MILLION

departments received a record-high $52.9 million in research funding, greatly accelerating the pace of scientific progress and discovery.

Importantly, the campaign raised $51.3 million for undergraduate and graduate student financial aid, making certain that all qualified students with the talent and ambition to succeed at the School are ensured access regardless of financial ability. Notably, the A. James & Alice B. Clark Foundation awarded $15 million to establish the A. James Clark Scholarship Program at Penn Engineering, the largest one-time gift to undergraduate support in the University's history. The Clark Scholars Program is a comprehensive, multifaceted educational experience for exceptional students from traditionally underrepresented backgrounds.

GRADUATE FINANCIAL AID

ORIGINAL GOAL $14 MILLION

TOTAL $14.7 MILLION

In addition to addressing educational inequality through financial aid, campaign funds also provided support for student and social enrichment. Gifts to the Cora Ingrum Fund directly benefited the Office of Diversity, Equity and Inclusion and strengthened Penn Engineering's commitment to building a more representative community through education, advocacy and opportunity. Furthermore, philanthropy fueled the School's response to COVID-19, designing and providing personal protective equipment and energizing research in the development of low-cost, rapid diagnostic tests.

The Power of Penn Engineering also promoted extraordinary engagement as hundreds of supporters unlocked three consecutive February Challenge gifts for Engineering Annual Giving. Alex T. Kreuger (ENG'96, W'96), Penn Engineering Advisor and Campaign Chair, sponsored the Challenge each year as a way for alumni to increase the impact of their unrestricted gifts.

UNRESTRICTED FUNDS

ORIGINAL GOAL $16 MILLION

TOTAL $16.2 MILLION

Special events like Penn to You brought some of Penn Engineering's most accomplished faculty members to locations around the world and enabled alumni, parents and friends to explore timely topics like medical innovation, artificial intelligence and sustainability. Even amid a global health crisis, virtual events like Dean Kumar's Homecoming Town Hall, the China Forum and the Penn-India Technology Forum were exceedingly well attended and kept our community connected throughout the pandemic.

The campaign will be remembered as a landmark achievement for the School. "I am deeply grateful to everyone who contributed to the overwhelming success of this campaign," says Dean Kumar. "Your support will be felt by generations of future students and faculty."

CAMPAIGN TOTAL

ORIGINAL GOAL $170 MILLION

TOTAL $250.3 MILLION

Advancing Change from Within

THE OFFICE OF DIVERSITY, EQUITY AND INCLUSION AT PENN ENGINEERING

When Brandon Joel Gonzalez (CS'19, ROBO'21) first arrived at the University of Pennsylvania, a sense of self-doubt eclipsed his typical first-year jitters. "I didn't know if I could really succeed in this domain or in my STEM courses," he says. "The introductory engineering courses were a massive struggle for me. It was material I had never been exposed to in high school, so I really doubted myself and my future."

For many students entering Penn Engineering, the self-doubt Gonzalez felt is a shared experience. Students might be away from friends and community for the first time, the first in their families to attend college, a member of a racial or ethnic minority group or from a household with fewer economic resources. Any or all of these situations can cause students to feel unseen, othered and ultimately out of place at Penn.

SINCE ITS FOUNDING, ODEI STAFF HAVE ADVOCATED TO CHANGE THE SYSTEMS IN THE SCHOOL THAT INFLUENCE RECRUITMENT, RETENTION, FUNDING AND MENTORSHIP.

This is when the programming, mentorship and camaraderie provided by the Office of Diversity, Equity and Inclusion (ODEI) can help to transform a student's Penn Engineering experience.

"As a School, we are unrelentingly focused on being a community of scholars who embody integrity and character and who are inclusive of diverse people and perspectives," says Dr. Laura Stubbs (MEAM BSE'79, MSE'80), Director of ODEI at Penn Engineering. "ODEI is here to support that mission by providing guidance, help and a safe space for our students, faculty and staff to share and exchange perspectives and experiences that help us to advocate for improvements to our culture and community."

ODEI is a hub of academic and social support in Penn Engineering that helps underrepresented students to thrive and succeed. "Upon my first introduction to ODEI (then known as the Office of Multicultural Programs) during the fall of my freshman year in 2015, I found a home away from home," says Faith Taliaferro (MEAM'19). "Their work is predicated on the goals of cultivating a sense of home and belonging for marginalized students within Penn Engineering and equipping them with the tools they need to be successful. ODEI was a space on campus where I felt important and looked after and where everyone believed in me with such conviction that I began to believe in myself, too."

A VITAL LEGACY

In the 1970s, long before ODEI at Penn Engineering, the late Joseph Bordogna, then-Associate Dean of Undergraduate Education, and staff member Miss Cora Ingrum had a pioneering vision: increase minority presence in engineering and decrease minority attrition at the University of Pennsylvania. The Philadelphia Regional Introduction for Minorities to Engineering (PRIME) program at Penn was established to help level the playing field for underrepresented students in math, science and engineering. The program graduated more than 5,000 students over 25 years who have gone on to have successful careers as engineers, researchers, teachers and entrepreneurs.

C.J. Taylor, Associate Dean for Diversity, Equity and Inclusion, and Laura Stubbs, Director of the Office of Diversity, Equity and Inclusion (ODEI), check in on the construction progress for the new ODEI suite on the second floor of the Towne Building.

In 1972, Ingrum was appointed Assistant to the Dean for Minority Programs and Director of Multicultural Programs in the School. The Office of Multicultural Programs (OMP) was founded in 1981, and under Ingrum's leadership, novel programs focused on the recruitment and retention of minority students at Penn Engineering were developed and implemented. Many, like the Pre-Freshman Program, have been institutionalized across the University. In addition, her desire to mentor, strategize with and support underrepresented students left an indelible mark on their lives.

When she retired in 2016, Ingrum concluded a 55-year tenure of helping students optimize their talents, capitalize on their cultural perspectives, realize their intellectual potential and thrive at Penn Engineering and beyond.

"When I launched my undergraduate and graduate careers at Penn Engineering, Cora Ingrum was there to help me persist and succeed," says Stubbs. "She was a thought leader who put her heart and soul into increasing the presence of underrepresented students, faculty and staff in the School. She encouraged and supported me and so many others. I intend to continue and build upon this legacy."

CREATING LEADERS

Since its founding in 1981, OMP and ODEI staff and their allies have advocated to change the systems in the School that influence recruitment, retention, funding, mentorship and more. In doing so, its staff have dedicated themselves to asking tough questions, working tirelessly to advance their mission, and using their own experiences to create a receptive, caring and nurturing environment to promote intellectual and personal growth.

ODEI's programming helps students to acclimate and find belonging in the School through academic coaching and mentoring programs that help students to engage with the community. Two initiatives, the Freshman Coaching Program (FCP) and the National Science Foundation Louis Stokes Alliance for Minority Participation (LSAMP) Summer Research Program, have 25-year legacies of success in helping underrepresented students not only to succeed academically at Penn, but also to become leaders in their fields of study.

"In addition to the rich cache of social support it provides, ODEI was also a treasure trove of academic access and opportunity," says Taliaferro.

The new ODEI suite will feature a modern, comfortable study area intended to encourage informal student gatherings and group work, along with a suite of offices and a conference room that can be connected to the study space to accommodate larger gatherings.

"I started my journey in research through the LSAMP Program, presenting at conferences and continuing research throughout the rest of my time at Penn. This set the tone for my current career in research at Boston Children's Hospital."

Support programming is not limited to undergraduates. This academic year, the School welcomed a record number of underrepresented graduate students, many of whom were awarded competitive Dean's Fellowships as master's students or Dean's Doctoral Fellowships. ODEI programming for graduate students includes an academic seminar that focuses on topics such as developing a work-life balance, building professional networks, the advisor/advisee relationship and professional communications.

A PLACE FOR BELONGING

In addition to student programming, ODEI advocates for changes that will improve the climate in the School and foster a deep sense of belonging for all students in Penn Engineering. Casual interactions with peers and mentors can be pivotal and can build or degrade confidence in equal measure.

Gonzalez recalls the experience where he was able to see past his self-doubt. "I took Introduction to Computer Systems with Dr. C.J. Taylor," says Gonzalez. "He took care to make it clear that everyone could succeed in his class as long as they put in the effort. He not only level-set my confidence, he also instilled a passion for electrical and computer engineering."

To further develop an inclusive environment, underrepresented student voices must be heard, and their experiences must be met with empathy and awareness. ODEI recruited an Alumni Board in 2020 to increase openness, relevance and collaboration in Penn Engineering. "The Alumni Board is like a compass that allows Penn Engineering to know if it is moving in the right direction to meet students' needs," says Yulanda Essoka, Associate Director of ODEI.

"What ODEI gave me is something that can never be repaid," says Taliaferro, who serves as co-President of the Board. "By being part of this effort, we can continue to shape student trajectories for the better and be a sanctuary for other students as the office was for me."

Place is just as important as programs and initiatives. Work on a new Center for Diversity, Equity and Inclusion on the second floor of the Towne Building is due to be completed by the end of the fall 2021 semester. The space features a modern, comfortable study area intended to encourage informal student gatherings and group work. The Center will also house a suite of offices for ODEI staff and a conference room that can be connected to the study space to accommodate larger gatherings.

"With the new space, we'll have a dedicated and welcoming place to support students' academic and personal success," says Stubbs. "We look forward to celebrating the 40th anniversary of ODEI in our new home and having a space that reflects the importance of the work that our office does and the immeasurable effects that our students and alumni have made on the world."

By Amy Biemiller

The Path Forward
for Penn Engineering

Camillo Jose (C.J.) Taylor, Raymond S. Markowitz President's Distinguished Professor in Computer and Information Science, was named Penn Engineering's inaugural Associate Dean for Diversity, Equity and Inclusion (DEI) in June 2020. Below he shares his thoughts on the state of the School and the strategy behind the plans for moving forward.

C.J. TAYLOR
Associate Dean for Diversity, Equity and Inclusion

Last summer, the murders of George Floyd, Ahmaud Arbery and Breonna Taylor—and the events that followed—turned a spotlight on systemic racism in our society. It forced many individuals and institutions to examine and reflect on how they participate in entrenched systems of inequality that have resulted in a sustained lack of equity for marginalized groups. The physical, emotional and financial toll this has taken, on African Americans in particular, is incalculable.

As we collectively and individually experience this era of social upheaval, it can be easy to feel disheartened. I want to say that, over this past year, when I look at the dedication and the mindset of my colleagues and the tenacity and resilience of our students here at Penn Engineering, I am excited and filled with hope for the future of our School.

I want to take a moment to acknowledge the foresight and courage that Dr. Joe Bordogna and Miss Cora Ingrum exhibited four decades ago in establishing the Office of Multicultural Programs, and to be realistic about the challenges that we, their successors in the Office of Diversity, Equity and Inclusion (ODEI), still face today. This year, we celebrate ODEI and the program's tremendous impact over the past 40 years. We must also recognize that we do not exist in a vacuum; systemic racism continues to present a "grand challenge" to us as a society and as a School.

I have always appreciated the fact that the opportunities that I have had to study and work in engineering were made possible by the people who came before me who broke down barriers and opened doors for my generation. I believe that part of my mission as an engineer and educator is to hold those doors open for others. In my position as Associate Dean for Diversity, Equity and Inclusion, I plan to help Penn Engineering build more and better pathways and to make the road smoother for the next generation of engineering students.

We need to build a culture where each member of our community believes they can achieve their full potential and feels empowered to do so. Penn Engineering's path to building this culture starts with funding and actionable DEI programs and initiatives. The School has committed $10 million over the next five years toward implementing these initiatives, and we've broken our efforts into three major areas: climate, faculty and student recruitment and retention, and community outreach.

"IN MY POSITION AS ASSOCIATE DEAN FOR DIVERSITY, EQUITY AND INCLUSION, I PLAN TO HELP PENN ENGINEERING BUILD MORE AND BETTER PATHWAYS AND TO MAKE THE ROAD SMOOTHER FOR THE NEXT GENERATION OF ENGINEERING STUDENTS."

As a School, the most important thing that we need to focus on is improving the climate. Everything else that we want to change, such as faculty and student recruitment, hinges upon having an inclusive community here at Penn where all of our students, staff and faculty feel seen, heard and empowered.

We plan to improve our climate through a range of efforts including training programs targeted at faculty, students and staff, new elements in our required ethics courses that focus on issues of diversity and fairness, an expansion of advising resources for URM students and a renewed emphasis on building a diverse faculty.

Penn Engineering, through our Advancing Women in Engineering (AWE) program, has been a leader in academia in supporting women in engineering but there are still women students who go through our programs who have never been taught by a woman professor. The experience of being able to see yourself reflected in the School's faculty is even more limited for our URM students. We have an opportunity and a responsibility to address this issue by redoubling our efforts to identify, cultivate and recruit talented faculty from a range of backgrounds and by advising graduate students who can become role models for the next generation.

Our community does not end at the campus border. Penn succeeds when Philadelphia succeeds and vice versa, and this goes for STEM education as well. The school district of Philadelphia is 50% African American and 25% Latinx, and it serves many talented students who are interested in STEM fields. Ensuring that underserved K-12 students in the Philadelphia area are engaged early in STEM means that they will be better prepared for higher education, whether that be at Penn or elsewhere.

I am proud to oversee K-12 programs like Inveniam, our STEM equity and innovation lab founded in partnership with Steppingstone Scholars. Outreach initiatives also allow us to tap into the tremendous resource we have in our Penn students. In every meeting I've had with our students, one of the first or second things that they talk about is their desire to be involved in outreach. We have extraordinary students here at Penn, and the ability to incorporate outreach into their Penn education means we graduate better engineers and more engaged citizens.

We are not unique in these challenges as an engineering school, as engineers, nor indeed as people. When you step back to think about it, an engineering school, where we are constantly inventing the future, is the perfect place to confront these issues. We must seize this chance to be creative in our search for solutions.

As a parent, an educator and an engineer, I am committed to this work, both to honor those who paved the way for me and countless others, and to secure the future for those who are to come.

The voices of our alumni and friends have been key in planning for the School. You are invited to use the provided links to learn more and stay updated as changes are implemented.

To provide feedback, please contact us by emailing odei@seas.upenn.edu.

FACULTY LEADERS

David F. Meaney

Solomon R. Pollack Professor, Bioengineering

Named Senior Associate Dean of Penn Engineering

Chinedum O. Osuji

Eduardo D. Glandt Presidential Professor, Chemical and Biomolecular Engineering

Named Chair of the Department of Chemical and Biomolecular Engineering

Ravi Radhakrishnan

Professor, Bioengineering and Chemical and Biomolecular Engineering

Named Chair of the Department of Bioengineering

Camillo Jose (C.J.) Taylor

Raymond S. Markowitz President's Distinguished Professor, Computer and Information Science

Named Penn Engineering's Inaugural Associate Dean for Diversity, Equity and Inclusion

Beth A. Winkelstein

Eduardo D. Glandt President's Distinguished Professor, Bioengineering

Named Deputy Provost of the University of Pennsylvania; Currently serving as Interim Provost

Shu Yang

Joseph Bordogna Professor, Materials Science and Engineering

Named Chair of the Department of Materials Science and Engineering

IN MEMORIAM

Joseph Bordogna

DEAN EMERITUS OF PENN ENGINEERING

Joseph Bordogna, Alfred Fitler Moore Professor of Engineering Emeritus in Electrical and Systems Engineering and former Dean of Penn Engineering, passed away on November 25, 2019, at the age of 86.

Dr. Bordogna grew up Philadelphia and was valedictorian of John Bartram High School. In 1955, he earned a bachelor's degree in Electrical Engineering from Penn while on a Naval ROTC scholarship. Following graduation, he served as a lieutenant in the U.S. Navy from 1955 to 1958.

Following his naval service, Dr. Bordogna earned a master's degree in Electrical Engineering and Computer Science from MIT in 1960, and then went on to earn a Ph.D. in Electrical Engineering from Penn in 1964. He joined the Penn faculty that same year as an Assistant Professor. He went on to become Director of The Moore School, an Associate Dean and finally Dean of Penn Engineering in 1981. During his 48-year tenure at Penn, he founded the Management & Technology Program (M&T) and received Penn Engineering's S. Reid Warren, Jr., and Penn's Lindback teaching awards. He was also the first master of Stouffer College House.

His research interests included optoelectronics, manufacturing systems, environmental technologies, management of technological innovation, educational innovation, and federal science and engineering policy. His contributions include early laser communications systems, electro-optic recording materials, holographic television playback systems and early space capsule recovery, receiving a commendation for history's first such recovery during Project Jupiter.

Throughout his career, Dr. Bordogna worked tirelessly to increase the representation and inclusion of underrepresented populations in STEM education. To this end, he founded PRIME (Philadelphia Regional Introduction for Minorities to Engineering) and the Commonwealth of Pennsylvania's Ben Franklin Technology Partners initiatives for university-industry technology commercialization.

In 1991, Dr. Bordogna left Penn to become head of the NSF's Engineering Directorate before being named Deputy Director by President Clinton in 1999 and subsequently serving as Chief Operating Officer. In addition, he was a member of the President's Management Council, the Federal Government's Technology Reinvestment Project Team (TRP), the Partnership for a

New Generation of Vehicles Committee (PNGV), and the President's National Science and Technology Council (NSTC).

Dr. Bordogna returned to Penn in 2005, earned emeritus status in 2009 and retired in 2011. At that time, the Joseph Bordogna Professorship was established in his name. His list of associations, honors and awards includes the NSF Distinguished Service Medal; the 2008 IEEE James H. Mulligan, Jr. Education Medal; the 1974 ASEE George Westinghouse Award; and the Lifetime Achievement Award of the D.C. Council of Engineering and Architectural Societies. He was an Eminent Member of Eta Kappa Nu; a member of the IEEE Honor Society; and a fellow of AAAS, ASEE, IEEE and the International Engineering Consortium.

Dr. Bordogna is survived by his wife, Frances Theresa (Wyandt) Bordogna; his son, Raymond Albert Bordogna (E'93) (Whitney Deas); his granddaughter, Avery Marguerite Bordogna; and numerous cousins.

Nabil Hasan Farhat

Nabil Hasan Farhat, Professor Emeritus in Electrical and Systems Engineering, passed away on November 3, 2020, at the age of 87.

Dr. Farhat obtained a bachelor's degree from the Technion-Israel Institute of Technology in 1957, a master's degree from the University of Tennessee in 1959, and a Ph.D. from the University of Pennsylvania in 1963, all in Electrical Engineering. He began his career at Penn as an Assistant Professor in 1964, and was awarded the Ennis Associate Professorship in 1973. He was promoted to full professor in 1976, and earned emeritus status in 2012.

Dr. Farhat's work included early groundbreaking research in microwave diversity imaging and tomography using spectral, angular and polarization degrees of freedom. Later he went into the fields of optoelectronic neural networks, stochastic learning, optical Boltzmann machines, and collective computation, learning and cognition in artificial neural networks. He was one of the first to demonstrate the optical implementation of neural networks, effectively the predecessor to the current-day fields of deep neural networks, machine learning and artificial intelligence. Because of his significant contributions, he became an internationally renowned leader in several fields.

Dr. Farhat's honors and awards include being named Fellow of IEEE and the Optical Society of America. In recognition of his contribution to Penn's educational mission, he received the Lindback Award for Distinguished Teaching, one of the University's highest honors for excellence in teaching.

Dr. Farhat is survived by his wife, Joan English Farhat; his brother, Amir Farhat; his sister, Malaka Safadi and her husband Bassam Safadi; brother-in-law and sister-in-law, John and Susan English; two nephews, Rami Safadi and Andrew English; two nieces, Reema Safadi and Alice English; and two great-nephews, Ryyan and Sam Safadi.

Noah S. Prywes

Noah S. Prywes, Professor Emeritus in Computer and Information Science, passed away on September 21, 2020, at the age of 95.

Dr. Prywes obtained a bachelor's degree in Electrical Engineering from the Technion-Israel Institute of Technology and then moved to the U.S. for graduate school. He first studied at the Carnegie Institute of Technology (now Carnegie Mellon University) and then attended Harvard University, where he obtained a Ph.D. in Applied Physics in 1954. Before coming to Penn, Dr. Prywes worked on early electronic computers at UNIVAC, leading the computing unit for the LARC computer, one of the world's first supercomputers.

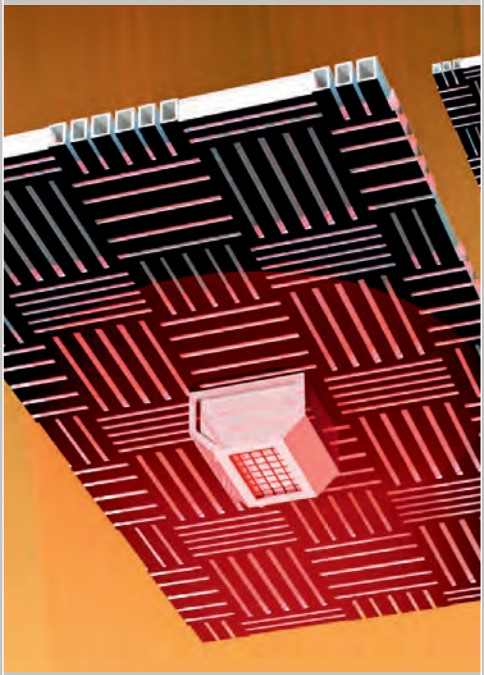
Dr. Prywes began his career at Penn in The Moore School as an Associate Professor in 1958. In 1968, he became a Professor in the new Department of Computer Science and his early doctoral students were some of the first to receive a Ph.D. from a Department of Computer Science. Dr. Prywes remained a Professor at Penn for almost three decades and earned emeritus status in 1996.

Dr. Prywes was a pioneer in computing technology. In the 1960s, he created Multi-List, one of the first relational database management systems. In the late 1960s and early 1970s, he advanced and commercialized timesharing, the predecessor to today's cloud computing. In the 1980s and 1990s, he was at the forefront of automatic programming, nonprocedural specification systems and reverse engineering, and the application of these technologies to parallel and distributed computing. In the early 2000s, he developed innovative speech technology for use in telephony. Dr. Prywes published prolifically, was awarded numerous patents, and was a Fellow of IEEE.

Dr. Prywes is survived by his wife of 67 years, Dr. Ruth W. Prywes; three sons, Menahem, Daniel and Ron Prywes; and seven grandchildren.

Firooz Aflatouni, *Associate Professor in Electrical and Systems Engineering*, received a 2020 Bell Labs Prize.

Ritesh Agarwal, *Professor in Materials Science and Engineering*, was elected a 2020 Fellow of the Optical Society.



J.D. Albert, *Lecturer in Mechanical Engineering and Applied Mechanics*, was named a 2020 National Academy of Inventors Fellow.

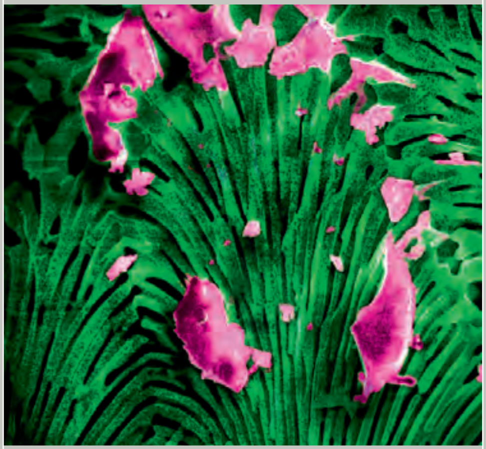
Sebastian Angel, *Raj and Neera Singh Term Assistant Professor in Computer and Information Science*, received a 2021 NSF CAREER Award.

Norman I. Badler, *Professor Emeritus in Computer and Information Science*, was elected to the 2021 Class of the ACM SIGGRAPH Academy.

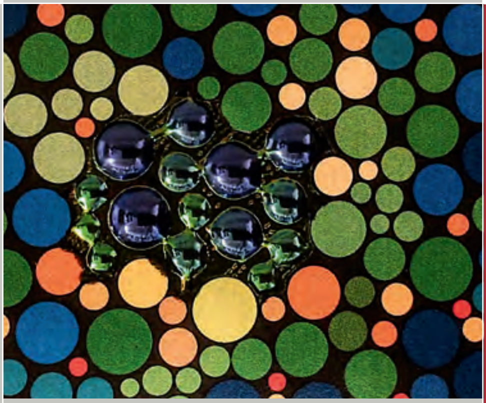
Dani S. Bassett, *J. Peter Skirkanich Professor in Bioengineering*, was named a 2021 Fellow of the American Physical Society (APS), a 2020 American Institute for Medical and Biological Engineering (AIMBE) Fellow and was named to the 2020 “World’s Most Highly Cited Researchers” list by The Institute for Scientific Information and the Web of Science Group.

Jason A. Burdick, *Robert D. Bent Professor in Bioengineering*, was named to the 2020 “World’s Most Highly Cited Researchers” list by The Institute for Scientific Information and the Web of Science Group and was elected a 2019 National Academy of Inventors Fellow.

Chris Callison-Burch, *Associate Professor in Computer and Information Science*, received the 2021 Penn Engineering Ford Motor Company Award for Faculty Advising.



Robert W. Carpick, *John Henry Towne Professor in Mechanical Engineering and Applied Mechanics*, received the 2021 Nanotechnology Recognition Award from the Nanoscale Science and Technology Division (NSTD) of AVS.



Vanessa Z. Chan, *Jonathan and Linda Brassington Practice Professor, Innovation and Entrepreneurship in Materials Science and Engineering*, was named Chief Commercialization Officer and Director of the Office of Technology Transitions for the Department of Energy.

Jennifer Phillips-Cremins, *Associate Professor and Dean’s Faculty Fellow in Bioengineering*, received a 2021 NIH Pioneer Award.

César de la Fuente, *Presidential Assistant Professor in Bioengineering*, received the inaugural Nemirovsky Engineering and Medicine Opportunity (NEMO) Prize and was named to the AIChE’s 2020 “35 Under 35” list.

André DeHon, *Professor in Electrical and Systems Engineering*, received the 2020 IEEE Computer Society Undergraduate Teaching Award.

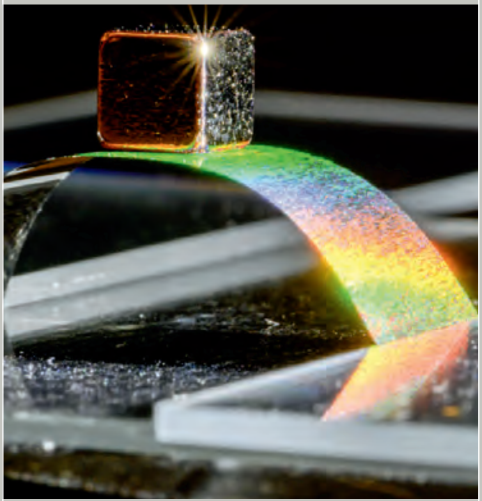
Eric Detsi, *Stephenson Term Assistant Professor in Materials Science and Engineering*, received a 2021 NSF CAREER Award and the 2021 Penn Engineering S. Reid Warren, Jr., Award.

Nader Engheta, *H. Nedwill Ramsey Professor in Electrical and Systems Engineering*, received the 2020 Isaac Newton Medal and Prize and the 2020 Max Born Award from the Optical Society.

Liang Feng, *Associate Professor in Materials Science and Engineering*, was named a 2020 Sloan Research Fellow and received the 2020 Penn Engineering S. Reid Warren, Jr., Award.

Alex J. Hughes, *Assistant Professor in Bioengineering*, received a 2021 NSF CAREER Award.

Deep Jariwala, *Assistant Professor in Electrical and Systems Engineering*, received the 2020 Minerals, Metals & Materials Society Frontiers of Materials Award.



Ning (Jenny) Jiang, *Peter and Geri Skirkanich Associate Professor of Innovation in Bioengineering*, received a 2021 Lloyd J. Old STAR Program grant from the Cancer Research Institute.

Sampath K. Kannan, *Henry Salvatori Professor in Computer and Information Science*, was named a 2019 AAAS Fellow.

Michael Kearns, *National Center Professor of Management & Technology in Computer and Information Science*, was elected to the National Academy of Sciences.

Tania Khanna, *Senior Lecturer in Electrical and Systems Engineering*, received the 2020 Penn Engineering Hatfield Award for Excellence in Teaching in the Lecturer and Practice Professor Track.

Bruce Kothmann, *Senior Lecturer in Mechanical Engineering and Applied Mechanics*, received the 2021 Penn Engineering Hatfield Award for Excellence in Teaching in the Lecturer and Practice Professor Track.

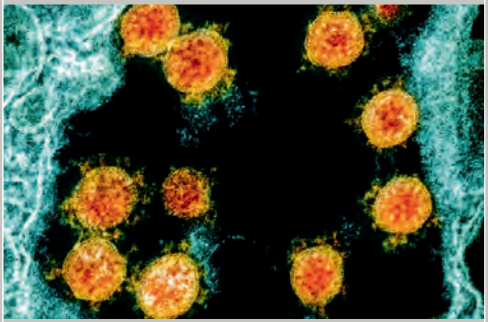
Daeyeon Lee, *Professor and Evan C Thompson Term Chair for Excellence in Teaching in Chemical and Biomolecular Engineering*, received the 2021 IDEA Prize to advance oral healthcare innovation.

Bomyi Lim, *Assistant Professor in Chemical and Biomolecular Engineering*, received the 2020 Korean Institute of Chemical Engineers (KIChE) President Young Investigator Award.

Brian Litt, *Professor in Bioengineering*, received a 2020 NIH Pioneer Award.

Nikolai Matni, *Assistant Professor in Electrical and Systems Engineering*, received a 2021 NSF CAREER Award.

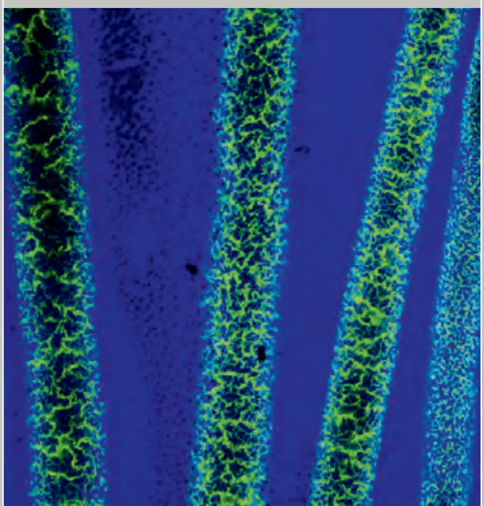
David F. Meaney, *Solomon R. Pollack Professor in Bioengineering and Senior Associate Dean of Penn Engineering*, received a 2021 Penn Lindback Award for Distinguished Teaching.



Marc Miskin, *Assistant Professor in Electrical and Systems Engineering,* was named a 2021 Sloan Research Fellow, received a 2021 Packard Fellowship for Science and Engineering, was named to *MIT Tech Review*'s 2021 "35 Innovators Under 35" list and received 2020 Young Investigator Awards from the Army Research Office and the Air Force Office of Scientific Research.

Christopher Murray, *Richard Perry University Professor in Materials Science and Engineering*, was named a 2020 Citation Laureate, a mark of "Nobel Class" research.

George J. Pappas, *UPS Foundation Professor of Transportation and Chair of Electrical and Systems Engineering*, was named a Berkeley EECS 2021 Distinguished Alumnus.



Paris Perdikaris, *Assistant Professor in Mechanical Engineering and Applied Mechanics*, received a 2021 Scialog Award for Collaborative Work in Bioimaging, a 2021 Early Career Prize from the Society for Industrial and Applied Mathematics (SIAM) and the 2020 Penn Engineering Ford Motor Company Award for Faculty Advising.

Linh Thi Xuan Phan, *Associate Professor in Computer and Information Science*, received a 2020 Penn Lindback Award for Distinguished Teaching.

James H. Pikul, *Assistant Professor in Mechanical Engineering and Applied Mechanics*, received a 2020 NSF CAREER Award and a 2020 Moore Inventor Fellowship.

Celia Reina, *William K. Gemmill Term Assistant Professor in Mechanical Engineering and Applied Mechanics*, received a 2021 NSF CAREER Award.

Shirin Saeedi Bidokhti, *Assistant Professor in Electrical and Systems Engineering*, received a 2021 NSF CAREER Award.

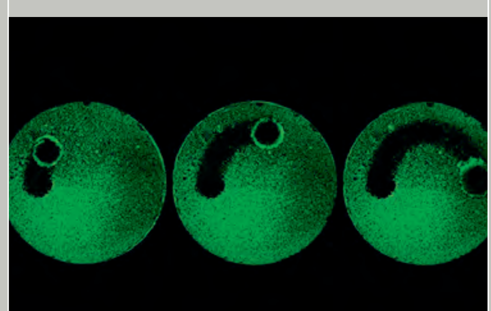
Kathleen J. Stebe, *Richer & Elizabeth Goodwin Professor in Chemical and Biomolecular Engineering*, was elected to the National Academy of Engineering (NAE).

Cynthia Sung, *Gabel Family Term Assistant Professor in Mechanical Engineering and Applied Mechanics*, received a 2020 Johnson & Johnson Women in STEM2D Scholars Award.

Kevin T. Turner, *Professor and Chair of Mechanical Engineering and Applied Mechanics*, received a 2021 Penn Lindback Award for Distinguished Teaching.

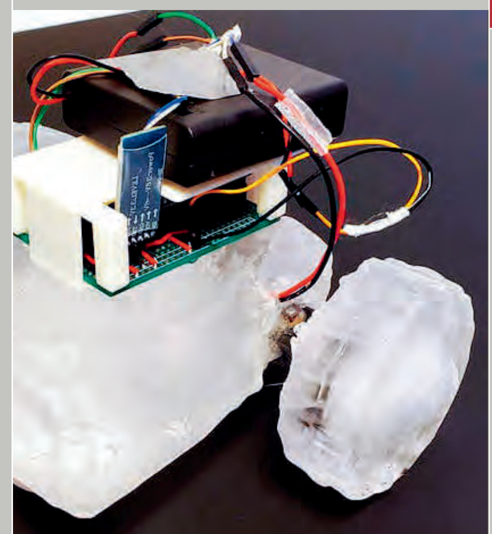
Lyle H. Ungar, *Professor in Computer and Information Science*, was named a 2020-21 AAAS Leshner Public Engagement Fellow.

Rakesh V. Vohra, *George A. Weiss and Lydia Bravo Weiss University Professor in Computer and Information Science*, received the 2020 SIGecom Test of Time Award.



Duncan J. Watts, *Stevens University Professor in Computer and Information Science*, was named a 2020 Andrew Carnegie Fellow.

Jennifer Wilcox, *Presidential Distinguished Professor of Chemical Engineering and Energy Policy in Chemical and Biomolecular Engineering*, was named Principal Deputy Assistant Secretary for Fossil Energy in the Department of Energy's Division of Fossil Energy.



Karen I. Winey, *Harold Pender Professor in Materials Science and Engineering*, received the 2020 Herman F. Mark Senior Scholar Award from the American Chemical Society (ACS) and the 2020 Braskem Award for Excellence in Materials Science & Engineering from The American Institute of Chemical Engineers (AIChE).

Shu Yang, *Joseph Bordogna Professor and Chair of Materials Science and Engineering*, received a 2020 Manufacturing PA Innovation Grant.

NEW FACULTY

Jacob Gardner
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Ph.D. in Computer Science
Cornell University

Sharath Chandra Guntuku
Research Assistant Professor, Computer and Information Science
Ph.D. in Computer Science
Nanyang Technological University Singapore

Dinesh Jayaraman
Assistant Professor, Computer and Information Science
Ph.D. in Electrical and Computer Engineering
University of Texas at Austin

Douglas Jerolmack
Professor, Mechanical Engineering and Applied Mechanics; Earth and Environmental Science
Ph.D. in Geophysics
Massachusetts Institute of Technology

Ning (Jenny) Jiang
Peter and Geri Skirkanich Associate Professor of Innovation, Bioengineering
Ph.D. in Biomedical Engineering
Georgia Institute of Technology

Kevin Johnson
University Professor, Computer and Information Science; Biostatis-tics, Epidemiology and Informatics
M.D. in Medicine; Johns Hopkins University School of Medicine

Benjamin C. Lee
Professor, Electrical and Systems Engineering; Computer and Information Science
Ph.D. in Computer Science
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Goodwin Gaw

INSPIRING PROFITABLE TEAMS

Sometimes finding the origin of a person's talent for business and drive to succeed is easy. For Goodwin Gaw, it began as a child when his father quizzed him on articles from *The Wall Street Journal* and taught him the importance of persistence.

"If you're going to be an entrepreneur," Gaw says, "you're going to be told 'no' 99 percent of the time, but when you find that one 'yes,' and you're right about it, then you're on the path to success."

After graduating from Penn's M&T Program, Gaw went on to earn a graduate degree from Stanford Engineering and then founded the property investment firm Downtown Properties in California. He became known as a risk taker, acquiring and revitalizing properties, and in 2005, he formed Gaw Capital Partners. He joined the School's Board of Advisors in 2019.

What is most rewarding about being an Advisor?
Seeing how passionate the Board members are about contributing to the School in a positive way and how willing they are to use their resources to help, whether it's a research program, an alumni cause, or understanding how our networks and knowledge can make a difference.

What is unique about Penn graduates?
My company employs quite a few Penn graduates. I'm told I'm biased, and I don't argue. I am biased, because the Penn graduate is more adaptable to the real world. With the world becoming more collaborative, and with so much new technology on the horizon, the cross-discipline is very important. With its collaborative programs, Penn equips its students for the world better than any other university.

What is your proudest achievement since graduating?
Finding my passion and turning it into a successful business that allows me to give back, whether it's to the schools that helped mold me into who I am or with projects that change cities for the better.

Where do you find the courage to take the risks you take?
I don't see them as risks. People say I like to tackle white elephants, but I think a lot of these white elephants have their own stories to tell, so if you listen closely, you can reinterpret them and tell new stories instead of sending them to the landfill. The courage comes from confidence, and that comes from building the right team to help execute ideas. Visionary ideas are just visions without the right team to make them reality.

What advice do you give your children regarding education and business?
Follow your hearts. Ultimately, I think all we can do is show them how to discover who they are, who they want to be, and what their passion is. Everyone has their own path. That's the joy of life: figuring it out and finding your way.

By Ryan Hampton

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PENN ENGINEERING PROUD

It's easy to show your Penn Engineering pride. Take, for example, Nick McGill (EE/ME/ROBO'14), wearing a Penn Engineering T-shirt from 2014, perhaps one he "borrowed" from brothers Steve or Will, also both Penn Engineering alums. A favorite Penn memory? Doing weekend hack-athons with friends to build sign language interpreters and robots controlled by hand waving. Fast-forward a few years and McGill has designed and taught classes at Penn with his Internet of Things industry experience. He is now working at the Pennovation-based startup InnaMed to develop a connected at-home blood diagnostic device.

If you are an alum or a parent of a Penn Engineer and would like to show your pride, please email us your story and a photo (info@seas.upenn.edu) or tag us on Instagram so that we can share your image on our social media channels.

#PennEngineeringProud
#ProudPennEngineeringParent