FORWARD FEST

RESOURCE GUIDE

March 2021

A YEAR OF FORWARD THINKING

A YEAR OF FORWARD THINKING

What Is A Year of Forward Thinking?

A Year of Forward Thinking spans the 2020–21 academic year and engages the entire Princeton University community — alumni, students, faculty, staff and friends — in a global conversation about pioneering solutions for today's challenges.

forwardthinking.princeton.edu

FORWARD FEST

What Is Forward Fest?

Forward Fest is a monthly online series of discussions with Princeton faculty, students, staff, alumni and other interested thinkers who will explore, engage and develop bold thinking for the future.

How to Use This Resource Guide

Binge as background reading to prepare for the Forward Fest discussions, follow along during the programming and use the information to fuel conversations with Princetonians and others about ideas that merit Thinking Forward together.

forwardthinking.princeton.edu/festival

FORWARD THINKERS

José Avalos
Assistant Professor of Chemical and Biological Engineering and the Andlinger Center for Energy and the Environment

Cliff Brangwynne
June K. Wu '92 Professor of Chemical and Biological Engineering and Director, Princeton Bioengineering Initiative

Celeste Nelson
Wilke Family Professor in Bioengineering, Professor of Chemical and Biological Engineering, and Director, Program in Engineering Biology

Ben Raphael
Professor of Computer Science

Kirsten Bibbins-Domingo '87
Lee Goldman MD Endowed Chair in Medicine; Professor and Chair, Department of Epidemiology and Biostatistics; and Vice Dean for Population Health and Health Equity, University of California San Francisco School of Medicine; Princeton University Trustee; Forward Fest moderator

THURSDAY, MARCH 18, 2021

3:30 PM – 4:45 PM EDT

Thinking Forward Bioengineering

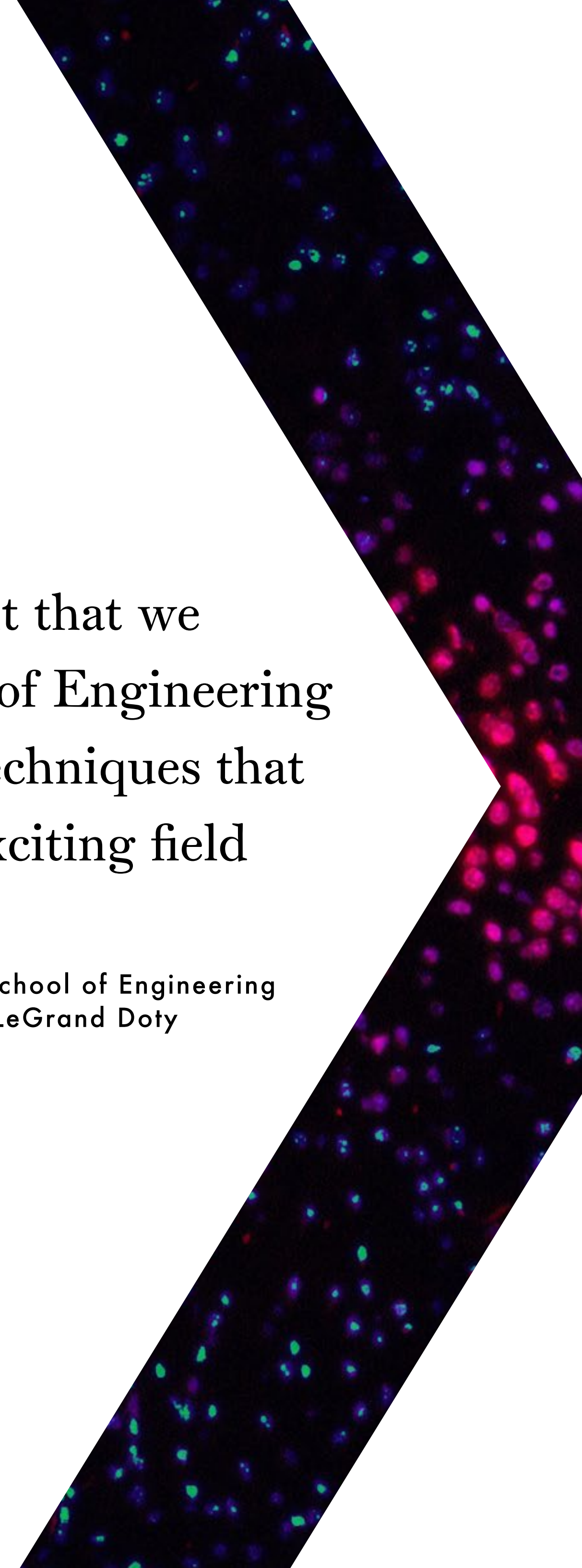
forwardthinking.princeton.edu/forwardthinkers

THINKING FORWARD:
BIOENGINEERING

BIOENGINEERING is the application of engineering analysis, design principles and technologies to unlock the secrets of complex biological systems. It spans all engineering disciplines as well as areas of natural science, social science and the humanities. With every new breakthrough, bioengineering is poised to transform society, with unlimited potential for positive impact on health, medicine and quality of life. Because of Princeton's interdisciplinary strengths and thriving internal and external partnerships, bioengineering at the University is at an inflection point for growth and service to humanity.

The Princeton Bioengineering Initiative, led by Cliff Brangwynne, supports and expands the bioengineering activities already underway at the University, and charts new directions in research, education and innovation at the intersection of the life sciences and engineering. "Black holes, quasars, supercomputers — nothing can compete with the complexity of even the most basic bacterial cell," Brangwynne said. "The cell is like a universe. Any place you point to with a very fine needle, you could spend a lifetime studying it." The Bioengineering Initiative aims to build synergy with a broad cross section of Princeton's research activities, including biomedical device development and other technologies that interface with biological systems; data science approaches in biology and medicine; and biomolecular, cellular and tissue engineering for human health.

> "Every single department that we have within the School of Engineering has tools and analysis techniques that can contribute to this exciting field of bioengineering."
>
> — ANDREA GOLDSMITH, dean of the School of Engineering and Applied Science and the Arthur LeGrand Doty Professor of Electrical Engineering



FORWARD THINKER

José Avalos

José Avalos is a biomolecular engineer who is researching ways that microorganisms can be infused with desirable traits to address challenging problems in sustainable energy, human health, sustainable manufacturing and the environment. Jointly appointed in the Department of Chemical and Biological Engineering and the Andlinger Center for Energy and the Environment, he runs a lab that integrates principles from microbiology, cellular biology, genetics, biochemistry, biophysics and engineering to the application and further development of technologies in synthetic biology and metabolic engineering. His team uses a technology called optogenetics — involving light to control cellular processes — to turn genes on and off at specific times to enhance the production of biofuels, drugs and commercial chemicals in bioreactors. Avalos is collaborating with Cliff Brangwynne on a project that seeks to engineer synthetic condensates that help turn yeast cells into chemical factories, potentially leading to the production of advanced biofuels.

Photo: Denise Applewhite, Office of Communications

» Using optogenetics, we can tell the cell what to do. And with biosensors we can see how well our signals are being received by the cell. »

MORE FORWARD THINKERS OF NOTE

Photo courtesy of Alexander Ploss

Alexander Ploss, associate professor of molecular biology — a biochemist who is reverse engineering the COVID-19 virus to create a less virulent version so that researchers can safely use it to test new therapies.

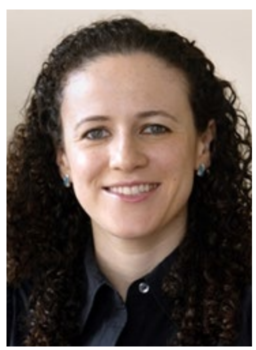


Photo courtesy of Department of Computer Science

Olga Troyanskaya, professor of computer science and the Lewis-Sigler Institute for Integrative Genomics — a computer scientist using big-data methods to predict mutations in the genome and develop precision medicine treatments for autism, cancer and other diseases.

FORWARD THINKER

Cliff Brangwynne

Cliff Brangwynne is an engineer whose primary research interests are the biology of intracellular organization, particularly in the role of intracellular liquid-liquid phase separation, a field that his discoveries pioneered. In 2009, he was the first to observe the liquid-like behavior of structures within roundworm cells. Since then, his research has uncovered clues for potential treatments for cancer and neurodegenerative diseases like Lou Gehrig's disease, Alzheimer's disease and Huntington's disease. "We try to figure out the underlying physics of how these structures assemble inside cells," said Brangwynne, who leads the Princeton Bioengineering Initiative. "It turns out that if you can start to pick apart those rules and understand how these structures in our cells are built naturally, then you can also understand something about when the process goes wrong."

Photos: Sameer A. Khan/Fotobuddy

» As an engineer, I'm interested in practical things — fixing problems. If you want to control some system, you first have to understand how it works. »

MORE FORWARD THINKERS OF NOTE

Martin Wühr

Tom Muir

Photos courtesy of Department of Molecular Biology

Martin Wühr, assistant professor of molecular biology and the Lewis-Sigler Institute for Integrative Genomics, and **Tom Muir**, the Van Zandt Williams Jr. Class of 1965 Professor of Chemistry, are working with Cliff Brangwynne to catalog the more than 10,000 proteins that give rise to activities such as cell division as well as specialized functions such as fighting infection. Their goal is to unlock our understanding of cellular structures, probe the basic biochemistry of life, and eventually inform the design and testing of new drugs and therapies.

FORWARD THINKER

Photo courtesy of the School of Engineering and Applied Science

Celeste Nelson

Celeste Nelson is a chemical and biological engineer who studies how groups of cells physically position or turn themselves into tissues and organs. Combining expertise from the cell biology, developmental biology and engineering communities, Nelson leads a group that develops tools and models that mimic tissue development, enabling rigorous quantitative analysis and computational predictions of the dynamics of morphogenesis — the developmental process that builds the lungs, kidneys and mammary glands. “We try to understand the cell biological mechanisms that lead to the formation of the beautiful architectures that are present within the tissues in your body, such as the airways of the lungs or the ducts of the mammary glands,” Nelson said. “On the flipside, we look at what physically takes place when these tissues are destroyed during disease processes, such as fibrosis, tumor formation and cancer progression.”

» People in science are by nature quite creative and see beauty in the [cellular] subjects that they’re investigating. »

MORE FORWARD THINKERS OF NOTE

Photo: Denise Applewhite, Office of Communications

Jared Toettcher, assistant professor of molecular biology and James A. Elkins, Jr. ’41 Preceptor in Molecular Biology — a bioengineer focused on dissecting how signaling pathways work together to orchestrate how cells decide when to differentiate, move, grow or die.

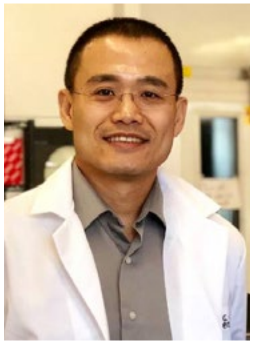


Photo: Denise Applewhite, Office of Communications”

Yibin Kang, the Warner-Lambert/ Parke-Davis Professor of Molecular Biology — a cancer biologist who is analyzing the molecular basis of cancer metastasis, combining molecular biology and genomics tools with animal models and advanced in vivo imaging technologies.

FORWARD THINKER

Photo: David Kelly Crow

Ben Raphael

Ben Raphael is a computer scientist who develops algorithms and mathematical models to study cancer biology by identifying and interpreting alterations in genomes, reconstructing tumor evolution, and discovering novel therapeutic interventions. Using sophisticated algorithms to explore regions of the genome whose roles in cancer have been largely uncharted, Raphael and an international team of researchers opened the door to a new understanding of the disease's genetic origins and how to track it throughout the body. "A better algorithm is like a better microscope," Raphael said. "When you look at nature with a magnifying glass, you may miss important details. If you look with a microscope you can see much more." Several of Raphael's algorithms have become benchmarks, and his computational approach to discover important cancer mutations has inspired many other researchers to tackle this problem.

» Technology for sequencing DNA in individual cells has limitations, and algorithms help researchers overcome these limitations. »

MORE FORWARD THINKERS OF NOTE

Photo: Sameer A. Khan/ Fotobuddy

Bryan Grenfell, the Kathryn Briger and Sarah Fenton Professor of Ecology and Evolutionary Biology and Public Affairs — a biologist investigating the population dynamics of infectious diseases.

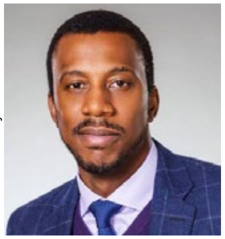


Photo: David Kelly Crow

Rodney D. Priestley, vice dean for innovation and the Pomeroy and Betty Perry Smith Professor of Chemical and Biological Engineering — a chemical engineer whose materials research has opened new possibilities for drug delivery, designer colloids and sustainable manufacturing.

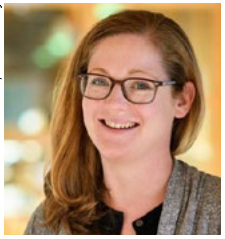
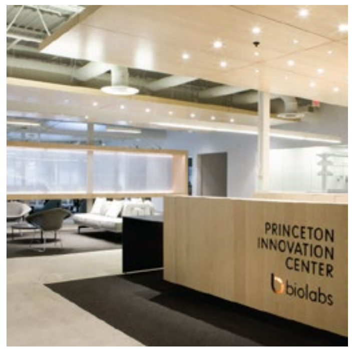


Photo: Sameer A. Khan/Fotobuddy

Britt Adamson, assistant professor of molecular biology and the Lewis-Sigler Institute for Integrative Genomics — a biologist using single-cell, CRISPR-based technologies to identify genes associated with response and resistance to antibody therapies.

FORWARD THINKING PARTNERSHIPS

Princeton Innovation Center BioLabs



Established in 2018 as a state-of-the-art facility near the Princeton campus, BioLabs fosters an innovative entrepreneurship ecosystem by supporting promising early-stage startups from Princeton faculty, students and alumni, as well as members of the wider New Jersey community. "Our best scholars are finding that collaborations with partners outside academia can assist both applied and basic research by helping them to identify interesting questions that matter to our society," said President Christopher L. Eisgruber '83.

Genentech

The Princeton Catalysis Initiative partnered with Genentech, a biotechnology company based near San Francisco, for five new collaborations in chemistry, molecular biology and chemical and biological engineering. The projects include novel formulations for drug delivery, earth-abundant metals for catalysis in pharmaceutical manufacturing, photo redox catalysis that can image molecules, and the complex interactions within microbial communities that could reveal new ways to turn "bugs into drugs."

Optimeos Life Sciences

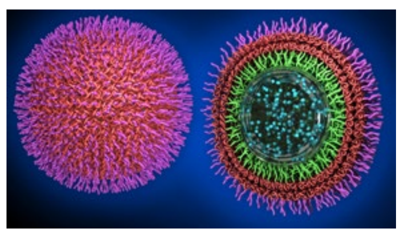
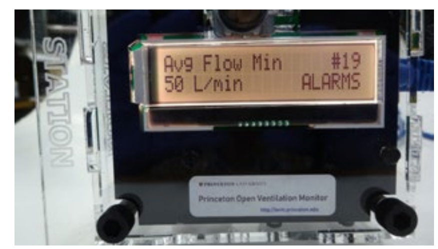


Illustration by Rachel Davidowitz

Optimeos Life Sciences, a BioLabs-based startup founded by Robert Prud'homme, professor of chemical and biological engineering, and Shahram Hejazi, an entrepreneurship specialist and lecturer in the Keller Center for Innovation in Engineering Education, partnered with six pharmaceutical companies to develop therapeutics using a Princeton-developed drug delivery technology. The collaborations have the potential to improve the effectiveness of medications for the treatment of diseases ranging from cancer to diabetes.

Penn Medicine



In the early months of the pandemic, Penn Medicine, which operates hospitals in Pennsylvania and New Jersey, lacked enough specialized respiratory monitoring systems machines. Andrew Leifer, an assistant professor of physics and neuroscience, stepped forward along with other Princeton researchers, professors, technicians, graduate students and staff members to build their own prototype from scratch. Within a month, they produced and delivered 50 of them.

FORWARD THINKING STUDENTS

Untangling the Web Of Cell Structures

Two Princeton graduate students collaborated on a project that illustrated how dewdrops on a spiderweb depict the physics behind cell structures. Sagar Setru *21 and Bernardo Gouveia examined how liquid-like proteins behave on cellular surfaces by studying the protein TPX2, which does not form liquid droplets in the cytoplasm but instead seems to undergo phase separation on biological polymers called microtubules. "We found that TPX2 first coats the entire microtubule and then breaks up into droplets that are evenly spaced apart, similar to how morning dew coats a spiderweb and breaks up into droplets," Gouveia said. TPX2 is associated with certain cancers, so understanding its behavior could lead to medical breakthroughs.

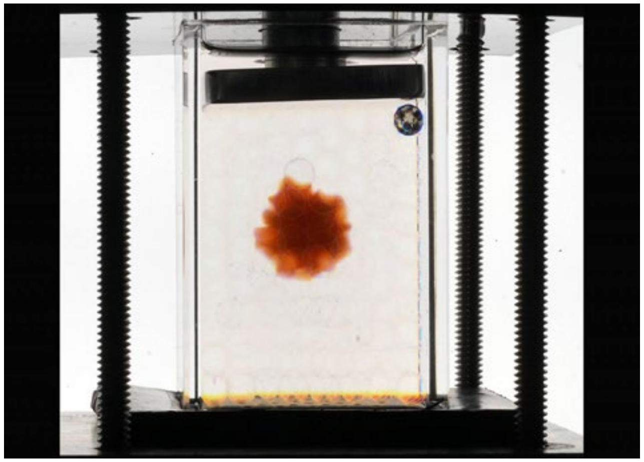

Sagar Setru *21


Bernardo Gouveia

"See-Through Soil"

Princeton students in the lab of Sujit Datta, an assistant professor of chemical and biological engineering, helped spark the research that led to the possibility of "see-through soil," a technology that could help crops survive drought. In summer 2018, Margaret O'Connell '20, then a Princeton undergraduate working in Datta's lab, devised a unique mixture of water and ammonium thiocyanate that changed water's refractive index so that scientists could better observe the effectiveness of hydrogels, extraordinarily absorbent plastic beads that serve as soil-like reservoirs for crops. "Our results provide guidelines for designing hydrogels that can optimally absorb water depending on the soil they are meant to be used in, potentially helping to address growing demands for food and water," Datta said.


Margaret O'Connell '20



FORWARD THINKING ALUMNI

Photo courtesy of Caltech

Frances Arnold ’79

Linus Pauling Professor of Chemical Engineering, Bioengineering and Biochemistry at the California Institute of Technology, and Director, Donna and Benjamin M. Rosen Bioengineering Center

In 2018, Arnold was awarded the Nobel Prize in chemistry for inventing directed enzyme evolution, which improves the “environmentally friendly manufacturing of chemical substances, such as pharmaceuticals, and the production of renewable fuels for a greener transport sector.” At Caltech she continues to develop evolutionary protein design methods to clarify principles of biological design and generate novel enzymes and organisms.

Photo courtesy of University of California, San Francisco

Kirsten Bibbins-Domingo ’87

Lee Goldman MD Endowed Chair in Medicine; Professor and Chair, Department of Epidemiology and Biostatistics; and Vice Dean for Population Health and Health Equity, University of California San Francisco School of Medicine; Princeton University Trustee

A general internist and cardiovascular epidemiologist, Bibbins-Domingo has studied observational epidemiology, pragmatic trials, and simulation modeling to examine clinical and public health approaches to prevention. She co-founded the UCSF Center for Vulnerable Populations at Zuckerberg San Francisco General Hospital, a center that focuses on actionable research to increase health equity and reduce health disparities in at-risk communities.

Photo courtesy of Rutgers School of Engineering

Joseph Freeman ’97

Associate Professor of Biomedical Engineering, Rutgers University

Freeman runs the Musculoskeletal Tissue Regeneration (MoTR) Laboratory at Rutgers, which explores the repair and regeneration of tissue through the use of tissue engineering techniques. He also co-authored the 2018 book, “Building Tissues: An Engineer’s Guide to Regenerative Medicine,” which lays out the science and future of healing and producing new tissues after disease or traumatic injury.

FORWARD THINKING ALUMNI

Photo courtesy of UConn Health

Cato T. Laurencin ’80

University Professor at the University of Connecticut; Albert and Wilda Van Dusen Distinguished Professor of Orthopaedic Surgery; Professor of Chemical and Biomolecular Engineering; Professor of Materials Science and Engineering; Director, The Raymond and Beverly Sackler Center for Biomedical, Biological, Physical and Engineering Sciences; Chief Executive Officer, The Connecticut Convergence Institute for Translational in Regenerative Engineering

A world-renowned surgeon-scientist in orthopedic surgery, engineering and materials science, Laurencin is a pioneer in the field of regenerative engineering, which includes the growth and regeneration of bone, ligaments and other musculoskeletal tissues. In 2016, Laurencin received the National Medal of Technology and Innovation, America’s highest honor for technological achievement, from President Barack Obama in ceremonies at the White House.

Photo courtesy of Frequency Therapeutics

Christopher Loose ’02

Co-founder and Chief Scientific Officer at Frequency Therapeutics; Co-executive Director of Yale University’s Center for Biomedical and Interventional Technology; and Associate Adjunct Professor of Urology in the Yale School of Medicine

Loose has excelled in the spaces where academia and entrepreneurship overlap. He co-founded two biotech companies and now serves as co-director of Yale University’s Center for Biomedical Innovation and Technology, an interdisciplinary initiative that helps students, staff, and faculty commercialize biomedical ideas. At Frequency Therapeutics, he’s led the company’s efforts to harness the body’s innate biology to reverse degenerative diseases, such as hearing loss and multiple sclerosis.

FORWARD THINKING ALUMNI

Photo courtesy of Stanford University

Alison Marsden ’98

Professor of Pediatrics (Cardiology) and Bioengineering, Stanford University

Marsden has channeled her training as a mechanical engineer into biomedical research and the application of engineering tools to make an impact on patient care in cardiovascular surgery and congenital heart disease. She runs the Cardiovascular Biomechanics Computation Lab at Stanford, which develops fundamental computational methods for the study of cardiovascular disease progression, surgical methods, treatment planning and medical devices.

Photo: Aaron E. Lin

Sofia Quinodoz ’13

Princeton postdoctoral researcher

Quinodoz’s studies about how cell structures contribute to disease received a boost in February when the Howard Hughes Medical Institute named her a Hanna Gray Fellow. The honor comes with a gift that will help fund her bioengineering research for the next eight years. Working in Cliff Brangwynne’s lab, she plans to combine a mapping technology she devised with advanced manipulation and imaging tools to give a complex, four-dimensional view of the genetic material within nuclear bodies.

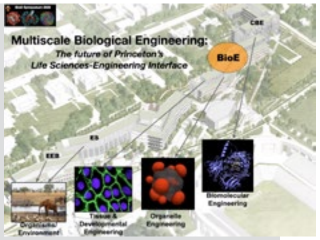
Gitai and Martin, at Martin’s 2019 Ph.D. thesis defense.

James K. Martin *19

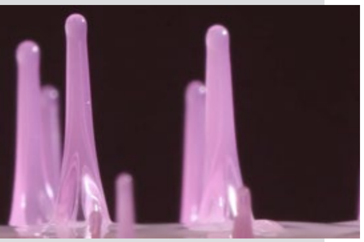
Postdoctoral Researcher at University of Chicago

While at Princeton working in the lab of Zemer Gitai, the Edwin Grant Conklin Professor of Biology and professor of molecular biology, Martin led the research team and was first author on the breakthrough paper about a “poisoned-arrow” antibiotic that attacks bacteria cells on two fronts — a discovery that could revolutionize antibiotic development and inspire others to design similarly effective ones. Now at the University of Chicago, after a year teaching in Urban Prep Chicago, Martin is investigating the role of the tumor nutrient microenvironment in pancreatic cancer therapy.

WATCH AND LISTEN



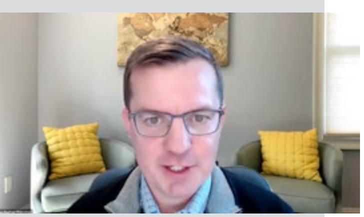
PRINCETON BIOENGINEERING SYMPOSIUM (series of 6 videos): Speakers from Berkeley, MIT, Bristol Myers Squibb and Johnson & Johnson joined the conversation in a November 2020 online event to highlight discovery, innovation and academic-industry partnerships centered around Princeton's growing bioengineering program.



GROWING ARTIFICIAL HAIR: Princeton researchers discovered tiny hair-like spindles grow when liquid elastic is coated on a disc and spun at intense speeds. The new method could be used at an industrial scale for production with plastics, glasses, metals and smart materials.

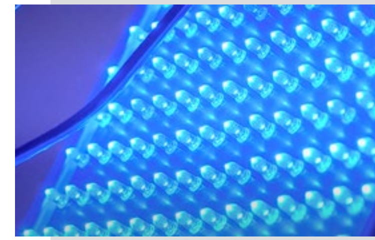
SHE ROARS PODCAST, FRANCES ARNOLD '79: The Nobel Prize winner explains how she views the balance between science and society and how engineering enzymes can expand the boundaries of green chemistry, biofuel production and more sustainable industrial processes.

ILLUMINATING LIQUID FORCES AT PLAY IN LIVING CELLS: Diana Chen '21 brings the Brangwynne Lab's research about cellular phase separation to life in a sweet stop-motion video that makes the science very digestible.



NEW FRONTIERS IN BIOMEDICAL DATA SCIENCE: Professor Ben Raphael moderated a conversation at the Engage 2020 online conference, bringing together industry and academic researchers from biomedical data science, computational oncology and computational immunology.

HONORARY LECTURE BY PROFESSOR ROBERT K. PRUD'HOMME: At Engage 2020, Professor Prud'homme delivered a lecture on his invention of flash nanoprecipitation — encapsulating drugs in nanoparticles for targeted delivery throughout the body — and its societal impact. He also spoke on his career at Princeton as an inventor and innovator.



BIOFUEL PRODUCTION USING LIGHT: Professor José Avalos explains how his team uses light to enhance the production of biofuels, drugs and commercial chemicals in bioreactors, which contain microorganisms such as yeast that have been metabolically engineered to make biological products.

MACHINE LEARNING FOR UNDERSTANDING GENOMICS: Barbara Engelhardt, associate professor in computer science, presents her TEDx Talk about how machine learning and artificial intelligence are changing the nature of biological research, especially genomics.

A METHOD TO SPY ON BACTERIAL BEHAVIOR IN COMPLEX ENVIRONMENTS: Professor Sujit Datta explains a new technique that makes it possible to track how bacteria move through complex and uneven environments akin to the tissues of the body or the sediments of underground aquifers.

A PLATFORM THAT SHARPENS IMAGES OF PROTEINS UNDER THE MICROSCOPE: Nieng Yan *05, the Shirley M. Tilghman Professor of Molecular Biology, describes how cryogenic electron microscopy allows researchers to capture the fine details of DNA, RNA and other proteins at an atomic resolution.

DISCUSSION

As you continue to think forward about bioengineering, brainstorm these questions to extend and deepen the conversation.

1. How does bioengineering fit in at a liberal arts university? What ways can you imagine the humanities informing and interacting with bioengineering?
2. What are some of the ethical considerations of bioengineering?
3. Bioengineering lies at the intersection of the life sciences and engineering and incorporates a number of disciplines. What specific criteria might one use to determine if a project falls under or outside the mantle of "bioengineering?"
4. How can breakthroughs in bioengineering better protect humanity from the next pandemic?
5. What do you think is a more important priority for bioengineering research: projects that attempt to solve human disease or projects that aim to protect all species, safeguard the environment and promote sustainability? Are there ways in which both are possible?

A YEAR OF FORWARD THINKING

Forward Fest is a monthly online event series open to the public.

THINKING FORWARD THE ENVIRONMENT

Thursday, April 15, 2021 | 4:00 PM EDT

What Are YOU Thinking Forward?
Share it now.
forward@princeton.edu
#PrincetonForward

For more information on future programming, visit
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