Accelerating impact through innovation and entrepreneurship
Welcome to Princeton Innovation, the University’s campus-wide initiative to extend the benefits of Princeton discoveries into the world to create solutions for humanity. We do this by building opportunities for entrepreneurship across the disciplines, supporting technology transfer, and engaging with industry, foundations and other external partners.

Our faculty, staff and students are at the center of an innovation landscape founded on rigorous research and scholarship. Princeton is home to world-renowned experts in data science, energy and the environment, the life sciences, the social sciences and the humanities. With major discoveries being made daily, we have an obligation to make sure these discoveries become innovations that can improve everyday lives.

Since launching Princeton Innovation in 2020, we’ve dramatically ramped up our activities, developing trainings, programs and opportunities that help our students, faculty and researchers ensure that their work makes a difference beyond academia.

In particular, we are expanding our focus on inclusive innovation as part of University President Christopher L. Eisgruber’s call to address systemic racism in the world and within our own community. One new program is our Empower 2021 conference, held this fall to celebrate Black entrepreneurship. Another is the Startup Training and Research Transition (START) program, part fellowship and part accelerator, created to attract and cultivate a pipeline of diverse entrepreneurs.

But our campus is only the start. In an important step forward for our regional leadership, the National Science Foundation (NSF) selected Princeton to lead an NSF Innovation Corps (I-Corps) Northeast Hub. The new hub, formed with partners Rutgers University and the University of Delaware plus a growing number

IDEAS INVENTIONS

Collaborative Bold Open Inspirational Inclusive Evolving

We are Princeton Innovation.

Princeton University Innovation is taking off.

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As we confront global challenges, connections between world-class research and the innovation ecosystem are more important than ever. At Princeton, we are eager to cultivate those connections on campus, in central New Jersey, and beyond.”
– Christopher L. Eisgruber,
Princeton University President

“Research is at the heart of discovery, and is the foundation of tomorrow’s scientific breakthroughs and technological innovations, expanding the frontiers of what is known and contributing to societal progress.”
– Pablo G. Debenedetti,
Princeton University Dean for Research

Princeton’s human scale, research intensity and culture of collaboration across disciplinary boundaries create a rich environment where new ideas and ingenuity thrive”
– Deborah A. Prentice,
Princeton University Provost

Princeton Innovation is taking off.

IDEAS INVENTIONS IMPACTS
In the Nation’s Service and the Service of Humanity

Princeton Innovation emerges from the University’s commitment to service, research and education.

Our curiosity-driven faculty, staff and students are shaping solutions to humanity’s challenges.

Through relationships with technology investors, industry and government, we are working to build a better future.

Fearless Firsts

Over the past year, Princeton Innovation rolled out exciting new programs to unleash the entrepreneurial spirit of faculty, staff and students.

Princeton-Wharton Executive Education

Hailing from disciplines across campus, from engineering to the arts, Princeton faculty and researchers built entrepreneurial skills in this weeklong program taught by the Wharton School of the University of Pennsylvania.

Lectures in Faculty Entrepreneurship (LIFE)

This new lecture series, inaugurated in fall 2020, featured leading experts in the field of startup creation, and covered topics such as legal incorporation, effective team building and product-market fit.
Princeton Startup Bootcamp

Over an action-packed three days in January and June, teams of graduate students and postdoctoral researchers forged and strengthened entrepreneurial ventures through the Princeton Startup Bootcamp, led by startup accelerator firm Techstars.

Engage 2020

With more than 50 sessions and 170 speakers, this three-day conference brought together Princeton researchers, innovators and entrepreneurs with those who can accelerate their work and its impact.

Dean for Research Award for Distinguished Innovation

Robert Prud’homme, Professor of Chemical and Biological Engineering, won the inaugural award for a method for creating nanoparticles to improve the delivery of drugs.
Starting in January 2022, Princeton University will lead a consortium of regional universities to form a new innovation network with a $15 million grant from the National Science Foundation (NSF).

The NSF Innovation Corps (I-Corps) Northeast Hub will broaden diversity in entrepreneurship and cultivate startups in health care, energy and the environment, computing, artificial intelligence, robotics, advanced materials and more.

The hub includes partners Rutgers University and the University of Delaware and five initial affiliates: New Jersey Institute of Technology, Rowan University, Temple University, Lehigh University, and Delaware State University, a Historically Black College and University (HBCU). Additional affiliate universities will be added in the coming years. icorpsnortheasthub.org

Vice Dean for Innovation Rodney Priestley will co-direct the hub with Julius Korley, Director of Entrepreneurship and Strategic Partnerships for the College of Engineering at the University of Delaware. Christina Pellicane will be the hub's Lead Instructor. Jannette Carey, Princeton Associate Professor of Chemistry, will be the Princeton Faculty Lead. Jeffrey Robinson, Associate Professor and Academic Director of The Center for Urban Entrepreneurship & Economic Development at the Rutgers Business School, will be the hub’s Research Lead.

Researchers at Princeton, University of Delaware (middle) and Rutgers University (bottom), as well as a growing number of affiliate universities, will access entrepreneurship training and support through the new NSF I-Corps Northeast Hub.
EMPOWER 2021

Aiming to broaden opportunities for university innovators who are underrepresented in entrepreneurship, Princeton University hosted the two-day conference Empower 2021: A Virtual Conference Celebrating Black Academic Entrepreneurship on Sept. 23-24.

This was the first in an annual conference series to support entrepreneurs in academia from different historically underrepresented groups. Empower 2021 brought together national thought leaders to share actionable knowledge and tools to transform university discoveries into companies and ventures that advance equitable societal and economic progress. The conference featured a pitch competition with a $100,000 top cash prize and other prizes including in-kind services, one-to-one meetings with select venture capital firms, and expert mentoring and coaching.

“This conference and pitch competition represent a tangible commitment to support inclusive entrepreneurship, help create a more diverse innovation ecosystem and reduce the racial wealth and opportunity gaps in American society,” said Princeton Vice Dean for Innovation Rodney Priestley. “We want this conference to result in action and opportunity by connecting entrepreneurs with resources and people that can make a difference to their ventures.”

Empower 2021 was sponsored by Princeton University, Mastercard Center for Inclusive Growth, Mintz, the National Urban League, Foundation for Health Advancement and EisnerAmper. empower.princeton.edu

START Entrepreneurs

The new Startup Training and Research Transition (START) fellowship and accelerator program will fund and support entrepreneurial investigators from across all academic disciplines to translate University research into impactful new ventures. START entrepreneurs will spend the first 12 months on campus working with a Princeton University faculty member engaged in translational research. The entrepreneurs then spend 18 months at the Princeton Innovation Center BioLabs, a coworking space for science startups, where they work full time as the founder of a new startup or nonprofit organization. Throughout the program, they will be supported by extensive entrepreneurship education, mentorship and funding from Princeton University.

The START program encourages applications from individuals who will contribute to the University’s diversity, broadly defined, including applicants of backgrounds underrepresented in academic entrepreneurship. Applications are due Dec 1. start.princeton.edu

The pace of growth of the entrepreneurial ecosystem on campus has been remarkable,” said Anne-Marie Maman, Executive Director of the Princeton Entrepreneurship Council. “With new programs, such as START Entrepreneurs, we look forward to increasing the ways that Princeton will have a positive impact on the world.” entrepreneurs.princeton.edu
Forming a startup can be exhilarating for academic researchers who want to see their ideas and innovations become real-world solutions. Each year, a number of Princeton researchers become startup founders with assistance and advice from Princeton Innovation, the Office of Technology Licensing and the Princeton Entrepreneurship Council.

**Offchain Labs:**

Growing the capacity of blockchain solutions

Co-founded three years ago, Offchain Labs expands the capacity of blockchain technologies to address needs beyond cryptocurrency.

Computer science professor Edward Felten started thinking about the idea behind Offchain Labs in 2014. He wanted to use blockchain technology — the same concept that underlies the cryptocurrency bitcoin — to secure online interactions between people.

Blockchain technology can provide secure online transactions in situations where two parties don’t trust each other. Instead of going through a credit card company or bank, parties employ computers to verify blocks of data stored in a chain.

But blockchain smart contracts are inherently slow, processing only a few transactions at a time, said Felten, who is the Robert E. Kahn Professor of Computer Science and Public Affairs, Emeritus. “We asked, how can we substantially increase the capacity while also lowering the cost of these transactions?”

His team started exploring ways to boost the capacity of transactions on a blockchain system called Ethereum, second only to Bitcoin in terms of size. Ethereum’s smart contracts enable developers to create secure apps for games, marketplaces, or financial operations such as currency exchange.

**Building a product**

By 2018, Felten and two graduate students, Steven Goldfeder and Harry Kalodner, had developed a solution for boosting Ethereum’s capacity. Their software, which they call Arbitrum, uses so-called offchain methods that don’t involve energy-intensive “mining” to verify blocks on the chain.

The team licensed the technology from Princeton University, co-founded Offchain Labs and raised seed funding. As the company’s momentum grew, Felten took a leave from the University, and as of July 1, 2021, became professor emeritus to focus full-time on the company as its chief scientific officer.

Arbitrum acts like a layer between the user and Ethereum to give all the security guarantees of the blockchain while using a lot less of the core Ethereum resource, Felten said. This reduces the amount of user activity each person does on Ethereum, leading customers to spend far less on Ethereum fees.

The product, which went live this summer, is easy to use, Felten said. “People who are familiar with Ethereum will just put in a different node address and talk to Arbitrum instead. That compatibility is super important. We really want it to be a ‘drop-in’ replacement.”

"University-founded discoveries can have a huge impact on improving lives, creating jobs and supporting new research discoveries,” said John Ritter, Director of Technology Licensing. "We help connect industry partners, investors and entrepreneurs with Princeton’s cutting-edge technologies and researchers to provide solutions to real-world problems."
Tenant Profile: Tendo Technologies

What started as a failed experiment has turned into a patented technology for measuring the flow of fluid in chemical and pharmaceutical equipment. Princeton professor Marcus Hultmark and his graduate students at first thought that their nano-sized temperature sensor was not working — but disappointment led to discovery when they realized that they were measuring fluid velocity, which is much more difficult to measure.

To develop the sensor, the team founded startup Tendo Technologies. In summer 2018, the team participated in the National Science Foundation (NSF) I-Corps program and the Keller Center eLab Summer Accelerator. The company was recently awarded federal Small Business Innovation Research (SBIR) funding. The team focuses on consumer products like medical devices for injections in the home and industrial automation processes where many fluids are measured simultaneously. The company is located at Princeton Innovation Center BioLabs, a coworking space for science startups about two miles from campus. tendo.tech and princetonbiolabs.com

"This is a great example of a fundamental research project leading to an unexpected discovery," said Marcus Hultmark, Associate Professor of Mechanical and Aerospace Engineering.
Engaging with Industry
Advancing research and innovation through partnerships

We live in an extraordinary time that calls on all of us to work together to overcome complex challenges.

Princeton’s Corporate Engagement and Foundation Relations (CEFR) team helps to forge multisector collaborations that advance research and innovation for the benefit of society. CEFR works across the University, and throughout the region and the globe, to foster mutually beneficial relationships that are strategic, catalytic and capacity-building.

The Dean for Research Innovation Fund for New Industrial Collaborations is one way that Princeton supports work with scientists in industry. The program requires a pledge of matching funding from the company in the second year.

One project selected for funding aims to cut the massive energy consumption driven by the expansion of data centers, cloud computing, artificial intelligence and the switch to 5G. Princeton’s Minjie Chen, Assistant Professor of Electrical and Computer Engineering and the Andlinger Center for Energy and the Environment, and his team are working with New Jersey-based semiconductor startup EnaChip Inc. to develop energy-efficient components based on the company’s unique silicon integrated magnetic components and packaging techniques. cefr.princeton.edu

Engineering’s New Era
New Dean drives growth, diversity and innovation

Andrea Goldsmith, a global leader in the development of wireless systems, became Dean of the Princeton School of Engineering and Applied Science (SEAS) in fall 2020. She is Princeton’s Arthur LeGrand Doty Professor of Electrical and Computer Engineering. Previously at Stanford University, she co-founded and served as Chief Technical Officer for Quantenna Communications and Plume WiFi. She holds 29 patents. Goldsmith’s vision for innovation and entrepreneurship includes:

A human-centered design initiative that differentiates design at Princeton

A cutting-edge innovation hub within SEAS to catalyze a new culture of innovation, out-of-box thinking and transfer to practice

An emphasis on fostering strong ties with industry through affiliates programs

Building alliances with accelerators, venture capitalists, and startup enablers

Essential to Goldsmith’s vision is the inclusion of the broad perspectives and experiences of a diverse community, which is critical for creating the new ideas and technologies needed to address complex societal challenges.

innovation.princeton.edu
National Lab Tech Transfer
Princeton Plasma Physics Laboratory: Ideas into technologies

Tapping ideas for studying the disc-like bands that form around planets or stars, scientists at the U.S. Department of Energy’s Princeton Plasma Physics Laboratory (PPPL) have invented a new type of centrifuge for separating the components of a liquid. The technology could be useful for applications such as treating wastewater from oil-sands processing, fruit-juice production, processing ink pigments and for other industrial applications.

Erik Gilson is one of several PPPL inventors of the advanced liquid centrifuge, which separates micron-sized materials from liquids much more quickly than standard centrifuges. The technology uses rings at the top and bottom of the device that spin at different rates, allowing the inner cylinder of the device to spin faster than the outer cylinder and providing better separation of materials.

The centrifuge is one of several PPPL technologies with its roots in fundamental discoveries in science and engineering, said Sir Steven Cowley, Laboratory Director and Professor of Astrophysical Sciences. “Erik is one of the many talented people at our national laboratory who are turning their ideas into viable technologies.”

Entrepreneurship Education
Keller Center’s eLab accelerates student ventures

Teams of Princeton undergraduate and graduate students gain the skills and know-how to launch new startups in this 10-week immersive program. The fledgling companies receive individualized mentorship and advising from industry experts and seasoned entrepreneurs.

This year marks the 10th anniversary of the eLab summer program, one of several offerings from the School of Engineering and Applied Science’s Keller Center that support student startup initiatives. After completing the program, many student teams have created viable ventures that are in business today.

Office Party is one of seven student-led teams that participated in the 2021 eLab Summer Accelerator program. Composed of four graduate students — Chase Galis and Sonia Sobrino Ralston of the Class of 2021 and Christina Moushoul and Reese Lewis of the Class of 2022 — in Princeton’s School of Architecture, the company aims to provide temporary event installations featuring immersive architectures with low environmental impact.

As Dean, I am excited to grow the engineering school significantly and ensure our place at the forefront of creating the knowledge, innovations and next generations of leaders our society needs,” said Andrea Goldsmith, Arthur LeGrand Doty Professor of Electrical and Computer Engineering, Dean of the School of Engineering and Applied Science.

Princeton will build a new home for Environmental Studies and the School of Engineering and Applied Science to support innovative teaching and research in the service of humanity.

“Window Shopping” is an installation by the student-led company Office Party that utilizes motion sensors to capture the silhouettes of those passing by, allowing re-occupation of retail space made vacant by Covid-19.

Image courtesy of Ennead Architects LLP/bloomimages.
FEATURED INNOVATORS

Each year, we highlight our faculty innovators and their teams at Celebrate Princeton Innovation, part of our Engage conference. Join us December 2, 2021. Register at innovation.princeton.edu.
Bioelectric programming of cell behavior and tissue healing

A device that can herd groups of cells like sheep, precisely directing the cells’ movements by manipulating electric fields, opens new possibilities to heal wounds, repair blood vessels or sculpt tissues.

The new system, assembled from inexpensive and readily available parts, enables researchers to control cellular movements within engineered tissues in a reliable and repeatable way. It does this by exploiting a phenomenon known as electrotaxis, in which electrochemical signals within the body can influence the migration, growth and development of cells.

Previous systems for studying cells’ responses to electric fields have been bespoke or handmade, raising issues of reproducibility, or required fabrication facilities that make them expensive and inaccessible.

The team calls the device SCHEEPDOG, for Spatiotemporal Cellular HErding with Electrochemical Potentials to Dynamically Orient Galvanotaxis (galvanotaxis is another term for electrotaxis). The device contains two separate pairs of electrodes that are used to generate electric fields along horizontal and vertical axes (akin to an Etch A Sketch), as well as recording probes to measure voltage and integrated materials to separate the cells from chemical byproducts of the electrodes. The voltage level is similar to that of an AA battery concentrated over the several centimeter-wide chamber containing the cells.

The team tested SCHEEPDOG using layers of mammalian skin cells and epithelial cells from the lining of the kidney, which are often used to study cells’ collective movements. By adjusting the electric field, the researchers could cause the cells to migrate in any direction or pattern. The team is expanding their studies to different cell types and contexts aimed at eventual applications like regenerating skin, blood vessels and nerve cells in damaged tissue, and has recently doubled the healing speed of cultured skin layers. They are working towards the development of next-generation bioelectric devices, such as e-Band-aids and electrically controlled immunotherapy.

This device gives us an amazing level of control over cells that we wouldn’t have expected to be possible, especially with thousands of neighboring cells executing these maneuvers on command.”
– Daniel Cohen

Researchers created a device that uses electrical fields to herd cells in specific directions, a feat with potential for use in tissue engineering and wound healing.
A new approach that directly measures the ability of the collective human gut microbiome to metabolize drugs promises to inform future drug design and guide efforts for personalized medicine.

The system evaluates how the microbial community in the intestines chemically transforms or metabolizes oral medications in ways that impact the drugs’ safety and efficacy. The new methodology provides a more complete picture of how gut bacteria affect drug safety and performance, and could aid the development of new drugs that are more effective, have fewer side effects, and are personalized to an individual’s microbiome.

The human gut microbiome is composed of hundreds of individual species of bacteria and varies greatly between individuals. Bacteria isolated from the gut microbiome can directly metabolize clinically used drugs, with important effects on toxicity or effectiveness. However, these contributions to drug pharmacokinetics have not been taken into account in the drug-development pipeline.

The microbiome-derived metabolism quantitative screen (MDM-QScreen) provides a measure of individual variability in the drug metabolism, degradation and metabolite formation. The screen could be used to inform drug design, enabling undesired effects on the drug by the microbiome to be discovered and eliminated early in the process. For drugs already in use, the screen could explain variability in drug response or toxicity.

The approach could also help personalize treatment according to the microbiome of each patient, predicting how a drug will behave and enabling changes to the therapeutic strategy if undesired effects are predicted.

“This approach allows us to gain a more comprehensive and realistic view of the microbiome’s contribution to drug metabolism.”

– Mohamed Abou Donia
INNOVATOR:
FATIMA EBRAHIMI

A new type of rocket thruster propels a spacecraft by taking advantage of the physical mechanism that accelerates solar flares. The thruster would apply magnetic fields to force particles of electrically charged gas, or plasma, to shoot out the back of a rocket at high velocity, causing forward momentum.

The new thruster would propel a spacecraft far more efficiently than currently available plasma thrusters, which use electric fields to propel particles. That higher efficiency could bring the outer planets within reach of astronauts.

The novel thruster concept would accelerate ionized gas particles using magnetic reconnection, a process found throughout the universe — including on the surface of the sun as solar flares — in which magnetic field lines converge, suddenly separate, and then join together again, producing lots of kinetic energy.

Changing the strength of the magnetic fields can increase or decrease the amount of thrust. By using more electromagnets and more magnetic fields, the researchers can in effect turn a knob to fine-tune the velocity.

The new thruster produces movement by ejecting plasma particles contained in magnetic bubbles known as plasmoids. The plasmoids add power to the propulsion. This is the only thruster concept to incorporate plasmoids.

Ebrahimi’s thruster concept is unique in that it can use plasma created from gases with light atoms without performance degradation. This flexibility in fuel use could allow refueling using gases extracted by mining asteroids.

“If we make thrusters based on magnetic reconnection, then we could conceivably complete long-distance missions in a shorter period of time.”
— Fatima Ebrahimi

A rocket-propelling thruster that works by harnessing the mechanism behind solar flares could someday carry humans to Mars and beyond.
INNOVATORS: ADAM FINKELSTEIN AND JIAQI SU

AI-driven method for producing high-quality audio recordings

A new method could improve the listening experience for podcasts, video voice-overs and audio books by using artificial intelligence (AI) to transform low-quality recordings of human speech into crisp and clear studio-quality tracks.

Voice recordings made with consumer-grade equipment in natural environments — including interviews conducted by phone or video chat — typically include background noise, reverberation and distortion. Existing AI-based methods for improving speech recordings have generally tackled a single aspect of audio quality, such as filtering out background noise or removing reverb.

The new method, which the researchers call HiFi-GAN (generative adversarial networks), is more of an all-in-one tool. Ultimately, the researchers hope to apply their framework to enable fully automated real-time speech enhancement.

The approach uses artificial neural networks, which are key tools of deep learning that mimic the interconnected architecture of biological neurons. The researchers train two separate networks that compete to improve audio quality. One network, called a generator, produces cleaned-up recordings of speech. The other network, called a discriminator, analyzes recordings to try to determine whether they are real studio-quality recordings or audio that has been cleaned by the generator.

The competition between these generative adversarial networks improves the method’s ability to produce clear audio. The generator and discriminator networks engage in a kind of arms race. The two of them ratchet their way up, each becoming more and more effective during training. When that process is complete, the discriminator is discarded, and what remains is a generator capable of producing clear audio.

“Deep learning has already had a huge impact in audio processing, and we expect it to become even more profound in the coming decade.”
— Adam Finkelstein

Innovators:
Adam Finkelstein, Professor of Computer Science
Jiaqi Su, Graduate Student in Computer Science

Collaborators:
Zeyu Jin, Princeton Ph.D. 2017, Adobe Research

Team members:
Pranay Manocha and Yunyun Wang, Graduate Students in Computer Science

Funding:
Princeton University Dean for Research Innovation Fund for New Industrial Collaborations; Adobe Research

Learn more:
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cs.princeton.edu/~af

An AI-powered approach provides automatic cleanup of recorded speech for podcasts, interviews, video voice-overs and audio books.
INNOVATOR:
ANDREW HOUCK

New materials that extend performance of quantum computers

A significant boost in the stability of qubits — the key components at the heart of quantum computers — could lead to significant improvements in performance.

Quantum computers work by manipulating quantum bits, or qubits — units of computing hardware that obey the laws of quantum mechanics — to tackle problems that ordinary computers cannot. The most advanced quantum computers rely on superconducting bits known as transmon qubits, but these can easily be destroyed by heat, contaminants or defects in its materials.

Now a team of researchers at Princeton has dramatically improved the performance of transmon qubits by replacing their superconducting innards with another, previously untried superconducting metal. The team used tantalum rather than the usual niobium to craft two key parts of the qubit, the capacitor and the microwave resonator.

Transmon qubits consist of nano-sized circuits patterned from superconducting materials onto the surface of a crystal such as sapphire. The depositing of tantalum in places that would normally contain niobium required substantial reconfiguring of equipment and procedures.

The result is a qubit with a lifetime that is three times longer previous qubits, a significant jump in viability. The resulting qubits have remarkably consistent performance. Replacing niobium with tantalum improved transmon qubit lifetimes across various designs, shapes and fabrication processes.

The researchers theorize that tantalum's performance can be explained by its reaction with oxygen. Tantalum oxides are insulating and can reduce loss in the device, whereas the oxides at the niobium surface can include noninsulating materials that lead to microwave loss.

“These qubits, which we engineered by systematically trying different superconducting materials, are delivering a whole new level of performance.”
– Andrew Houck

The staying power of the qubits at the heart of quantum computers can be dramatically improved by crafting components from tantalum (blue) on sapphire (gray).
A cost-effective and environmentally friendly way to recycle lithium-ion batteries

A new method for recycling lithium-ion batteries could help solve the looming shortage of critical metals, including lithium, cobalt, nickel and manganese, while reducing waste.

The demand for lithium-ion batteries is likely to increase as auto manufacturers boost production of electric and hybrid vehicles. Yet the recycling of lithium-ion batteries requires high amounts of energy and produces significant chemical waste.

Princeton researchers have invented an acid-free and energy-efficient process for regenerating the lithium-bearing oxide materials as well as other valuable metals from the batteries. Today’s techniques rely on acids to dissolve battery materials, resulting in the generation of waste that is harmful if released to the environment.

The team has pioneered a multistep battery-recycling approach. They start by detaching battery materials from their housings with water-based solutions to physically separate the positive and negative electrode materials. Additional steps filter intact and damaged particles.

They then expose the positive electrode materials to a low-temperature plasma, a gas containing charged molecules and electrons. The plasma reacts with electrode contaminants, allowing the removal of these contaminants at low temperature without using acids.

The final step is recovery of the particle shape and crystalline structure of the materials to create new battery electrode materials. The team has formed a startup company, Princeton NuEnergy, to develop the technology.

"Our method of battery recycling offers advantages in cost savings, energy efficiency and environmental protection.”

– Bruce Koel

From left: Yiguang Ju, Chao Yan, Bruce Koel and Xiaofang Yang
INNOVATORS: RUBY LEE and GUANGYUAN HU

Tiny AI module for detecting smartphone theft and anomalous behavior

A built-in hardware system could rapidly detect when a thief tries to use a stolen cell phone to access the phone’s data and online information.

The system uses artificial intelligence (AI) to evaluate data from the phone’s motion sensors to distinguish if the phone is being used by its rightful owner. Phone thieves move and manipulate the phone in a different way than would its true owner. Data collected from the phone’s motion sensors, such as its accelerometer and gyroscope, can yield a profile of the rightful owner.

The new system, known as Smartphone Imposter Detector, uses an AI technique known as deep learning enhanced with statistical tests to quickly detect anomalous handling of the phone. The system can then prevent access to sensitive information or completely shut the phone down. The smartphone owner could set preferences so that only trusted users are allowed.

The approach is supported by a tiny hardware module that can be added to the phone to implement the Smartphone Imposter Detector algorithm. The module adds minimal energy consumption and outperforms existing machine-learning algorithms.

Through the use of deep learning, the module learns the phone owner’s behavior patterns. Unlike other approaches, the module never shares this information via the cloud, significantly reducing user data exposure.

The module could be used beyond the smartphone application to detect anomalous behavior in critical infrastructures like the power grid, other cyber-physical systems and internet-of-thing (IOT) devices. It can detect anomalous behaviors by using hardware event counters built into microprocessors rather than motion sensors.

We have designed a hardware AI module that is very simple to implement, does not require any exotic technologies, and yet can defeat attackers, from smartphone imposters to power-grid attackers.” – Ruby Lee

We have designed a hardware AI module that is very simple to implement, does not require any exotic technologies, and yet can defeat attackers, from smartphone imposters to power-grid attackers.” – Ruby Lee

A tiny AI module can detect cell-phone theft and be adapted to monitor cyber-security systems and other smart devices.
An inexpensive device for monitoring breathing and airflow in noninvasive ventilator systems such as COVID-19 ventilator helmets is being made widely available through an open collaboration.

Noninvasive ventilators are a form of respiratory support that is gentler on the lungs and involves a plastic helmet placed over the patient’s head to deliver an enriched oxygen environment. But at the onset of the pandemic, hospitals needed specialized machines to monitor the breathing patterns and flow of oxygen to patients.

In spring 2020, in response to the call from the University of Pennsylvania hospital system (Penn Medicine), researchers from across the Princeton University campus came together to design and build a device to monitor airflow and measure patients’ breathing. They assembled the flow meter from inexpensive and readily available parts.

The flow meter sits by each patient’s bedside, feeding data to a centralized panel where medical staff can monitor the conditions of numerous patients. The machines monitor the flow of oxygen to the patients and provide a detailed record of each patient’s respiration and other data to help doctors follow the progression of the disease.

Their goal is to help medical professionals provide optimum care for patients being treated for COVID-19 and other respiratory disorders, while minimizing mortality and adverse long-term effects. The Princeton flow sensors provide new monitoring capabilities compared to what is commercially available and can do so at a lower cost.

The University has released all details of this technology publicly. A Brooklyn, New York-based company, Nanotronics Health LLC, plans to build and distribute the flow meters to hospitals and other patient settings.

The goal is to help patients with COVID-19, and to be able to work toward that goal was just tremendous. We have had involvement at all levels: faculty, students, postdocs, staff. It’s amazing.”
– Andrew Leifer
INNOVATOR:
JOSHUA RABINOWITZ

Therapy that robs cancer of its growth potential

By blocking a key enzyme, researchers have developed a new approach that could treat tumors, blood cancers and autoimmune disorders.

Researchers at Princeton have found a way to slow the growth of tumors by targeting a key enzyme involved in the conversion of a common dietary amino acid, serine, into building blocks of DNA called purines. They discovered a handful of small molecules that inhibit this enzyme, known as serine hydroxymethyl transferase (SHMT).

The team reported in 2017 that SHMT-inhibitors can block the growth of many human cancers, and that B-cell lymphomas were particularly sensitive. In 2020, they showed in mice that SHMT inhibition offers a complementary strategy to the chemotherapy drug methotrexate for treatment of acute T-cell leukemia. The researchers believe that SHMT inhibitors could block malignant solid tumors, blood cancers, and autoimmune disorders including rheumatoid arthritis, psoriasis, lupus, and Crohn’s disease.

SHMT functions enzymatically to create simple molecules called one-carbon units, which are carried by co-factors known as folates, and are key inputs to purine synthesis. The inhibition of other aspects of folate metabolism is an established mechanism of therapy for a variety of human cancers and autoimmune diseases. For example, permetrexed, a leading treatment for lung cancer that is based on discoveries made at Princeton, targets folate metabolism.

Until the work by Rabinowitz and team, there were no published inhibitors of SHMT enzymes in mammals, including humans. Their work covers inhibitors of two kinds of SHMT, one located in the main body of the cell, and the other in the organelle known as the mitochondria.

“We were surprised to discover that a subset of previously identified compounds that inhibit SHMT in plants also show efficacy against the mammalian form of this enzyme. We’ve now made major progress towards turning these initial leads into drugs.”
– Joshua Rabinowitz
INNOVATORS:
SAM WANG
AND HENK-JAN BOELE

Smartphone-based neurobehavioral testing in the blink of an eye

An app that turns an ordinary mobile phone into a device for conducting neurobehavioral evaluations could make it easier and more cost-effective to diagnose neurological disorders.

The BlinkLab smartphone application enables remote neurobehavioral testing in children and adults to help diagnose and monitor neurological disorders such as schizophrenia, autism and attention deficit hyperactivity disorder. The app, which evaluates eye movements and blinks, can also be used in neuroscience and psychology research to study fundamental mechanisms underlying learning and memory formation.

Until now, these tests have required dedicated hardware in a permanent lab environment with substantial face-to-face interaction between researcher and participant. No face attachments are needed for this user-friendly device, which makes it especially suitable for infants and patients with sensory issues.

The BlinkLab smartphone app allows remote performance of neurobehavioral tests using the user’s own cell phone. People can do the tests by themselves at home following the user-friendly instructions provided by the app.

Experiments can be programmed by the health-care professionals or researchers and selected from a list on the smartphone by the user. Data acquired with BlinkLab can be securely shared with health-care professionals or researchers.

During a typical evaluation, the user will watch an entertaining movie or play a video game while the smartphone delivers short auditory and visual stimuli. A test takes about 10-20 minutes. BlinkLab measures the user’s responses, and, using state-of-the-art computer vision algorithms, provides a behavioral readout that characterizes specific movements.

This app is easy to operate, substantially reduces the costs of studies, and produces reliable and reproducible results.”
– Sam Wang

BlinkLab: Smartphone-based Neurometric Testing

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A smartphone app could provide remote neurobehavioral and psychological evaluations, saving time and money.
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ENGAGE 2021


December 1-2

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- **The triple helix comes to life.** Opportunities for industry and non-academic partners to collaborate with Princeton research and innovation.
- **Entrepreneurship on the rise.** A startup showcase. Find money. Expand your network. Tap into government support for industry partnerships and startups.
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