Together into the Unknown

2021 Annual Report

Carl R. Woese Institute for Genomic Biology

DIRECTOR'S MESSAGE

GENE E. ROBINSON

We live in a complicated world—

one that constantly requires us to design clever solutions to seemingly daunting problems. To do so, we often have to use multiple approaches that analyze research questions from different angles, but this demands varied perspectives. It is therefore important that we remember our commitment to welcome diverse viewpoints into our scientific community and to maintain those social connections so that everyone feels assured of their acceptance.

We have addressed these goals in our outreach efforts, described in this year's Annual Report, by reconsidering how each of our programs promotes open dialogue between the public and

our institute. For example, we organized events for all ages to instill the feeling of wonder for the natural world that most of us experience in our daily lives. By doing so we have trained several new generations of scientists in science communication, worked towards fulfilling our goals as a land-grant institution, and made new friends who have generously contributed to our efforts. Although we still have much to do, hopefully one day we can come to expect diversity in science as a way of life instead of wondering why certain voices seem to be absent from our conversations.

The IGB's biggest strengths are its multidisciplinary research themes that capitalize on the recent advances in genome science and technology. With faculty from 40 departments across the university, we use an array of different approaches to solve questions to benefit society. At first blush it may seem like each theme has very different research objectives. However, as you will discover in this Annual Report many of them overlap at a high level. They include developing better therapeutics for a wide range of diseases, fortifying crops in the face of global warming, or understanding the underlying causes of stress in different animals. The stories of the people behind these studies remind us that it is essential to bring people together from across the globe to enrich our research efforts. The Annual Report will give you the chance to walk a mile in their shoes as they trace their journey to IGB.

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In 2021 we worked together to make several significant advances, marked by prestigious awards, filing numerous patents, and over 1000 papers published. However, as we slowly emerge from a difficult few years and face an uncertain future in terms of new COVID variants, conflicts on distant shores, and ongoing natural disasters, it is crucial to remember that we need to band together if we hope to move forward into a better world. As we have learned during our isolation in the past two years, a sense of community can get us through difficult times.

As they say: "If you want to go fast, go alone; but if you want to go far, go together."

Gene E. Robinson
Director
Carl R. Woese Institute for Genomic Biology

Carl R. Woese Institute for Genomic Biology: Where Science Meets Society

IGB's research is organized into several themes, each of which comprises multiple laboratory groups that work together in pursuit of their scientific goals. Broadly, the themes study plants and how they interact with their environment, new therapeutic agents, diagnostic tools, and animal and human health. Their work is enriched through collaborations with the community as well as academic, governmental, and industry partners.

Research Themes and Centers

	Health and Wellness	Agriculture and Environment	Technology and Society
Anticancer Discovery from Pets to People (ACPP) Develops cancer treatments in pet animals that translate to human disease	✓		✓
Biocomplexity (BCXT) Explores the origin of life and the behavior of biological systems	✓	✓	✓
Biosystems Design (BSD) Applies engineering principles to real and artificial biological systems	✓	✓	✓
Center for Advanced Bioenergy and Bioproducts Innovation (CABBI) Develops ways to grow bioenergy crops, transform biomass into valuable chemicals, biofuels, and bioproducts		✓	✓
Center for Genomic Diagnostics (CGD) Identifies reliable biomarkers of disease and develops technologies to detect those biomarkers	✓		✓
Environmental Impact on Reproductive Health (EIRH) Studies reproductive function and fertility disorders and develops therapeutic tools	✓		✓
Genomic Ecology of Global Change (GEGC) Studies the intersection of plant genomics and global climate change	✓	✓	✓
Gene Networks in Neural and Developmental Plasticity (GNDP) Examines the effects of coordinated gene activity on biological diversity	✓		✓
Genome Scale Engineering Center (GSE) Develops tools to allow rapid engineering of new organisms for the production of industrial compounds		✓	✓
Genomic Security and Privacy (GSP) Considers the implications of genomic applications on an individual's security and privacy	✓		✓
Infection Genomics for One Health (IGOH) Examines how microbes in human-inhabited environments influence health and disease	✓	✓	✓
Microbiome Metabolic Engineering (MME) Explores the relationships between human microbiota, environment, and health	✓	✓	✓
Mining Microbial Genomes (MMG) Discovers small molecules that might provide new medical solutions	✓	✓	
Multi-Cellular Engineered Living Systems (M-CELS) Develops *in silico*, cellular, and artificial components for precision assembly of biomachinery and computing processors	✓		✓
Regenerative Biology and Tissue Engineering (RBTE) Studies the replacement or regeneration of tissues and organs	✓		✓

Strategic Partnerships

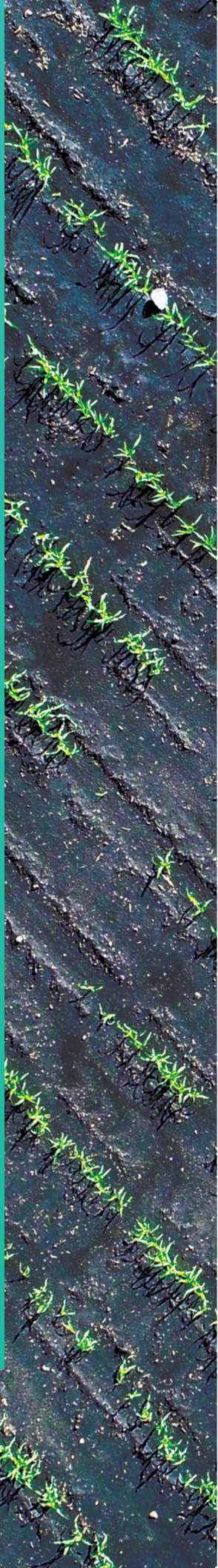
	Health and Wellness	Agriculture and Environment	Technology and Society
HPCBio High Performance Biological Computing was created to address the need for a structure that could supply infrastructure, user support and training, and R&D capability in computational genomics to the Illinois research community. HPCBio provides a single, straightforward point of access, open to researchers from all campus units, helping them to find solutions to their biomedical data management and analysis problems.			
Microbial Systems Initiative The goal of the Microbial Systems Initiative is to sustain a vibrant microbial sciences research and training enterprise at Illinois. Illinois microbial systems research addresses critical problems in health, agriculture, energy, and many other sectors. The MSI carries out ongoing activities to build collaboration across disciplines, provide world class training opportunities, and build environments of inclusive excellence.			
Molecule Maker Lab Institute The Molecule Maker Lab Institute is an interdisciplinary initiative with leaders in artificial intelligence and organic synthesis intensively collaborating to create frontier AI tools, dynamic open access databases, and fast and broadly accessible small molecule manufacturing and discovery platforms. Advanced AI and machine learning methods enable the MMLI to achieve AI-enabled synthesis planning, catalyst development, molecule manufacturing, and molecule discovery.			
Personalized Nutrition Initiative The Personalized Nutrition Initiative is a campus-wide initiative under the leadership of the Office of the Vice Chancellor for Research and Innovation, in partnership with the IGB and the College of Agricultural, Consumer and Environmental Sciences, to facilitate transdisciplinary collaborative efforts across campus to answer fundamental questions regarding how nutrition modulates health and disease across the lifespan and to translate that information to clinical care and to the public.			

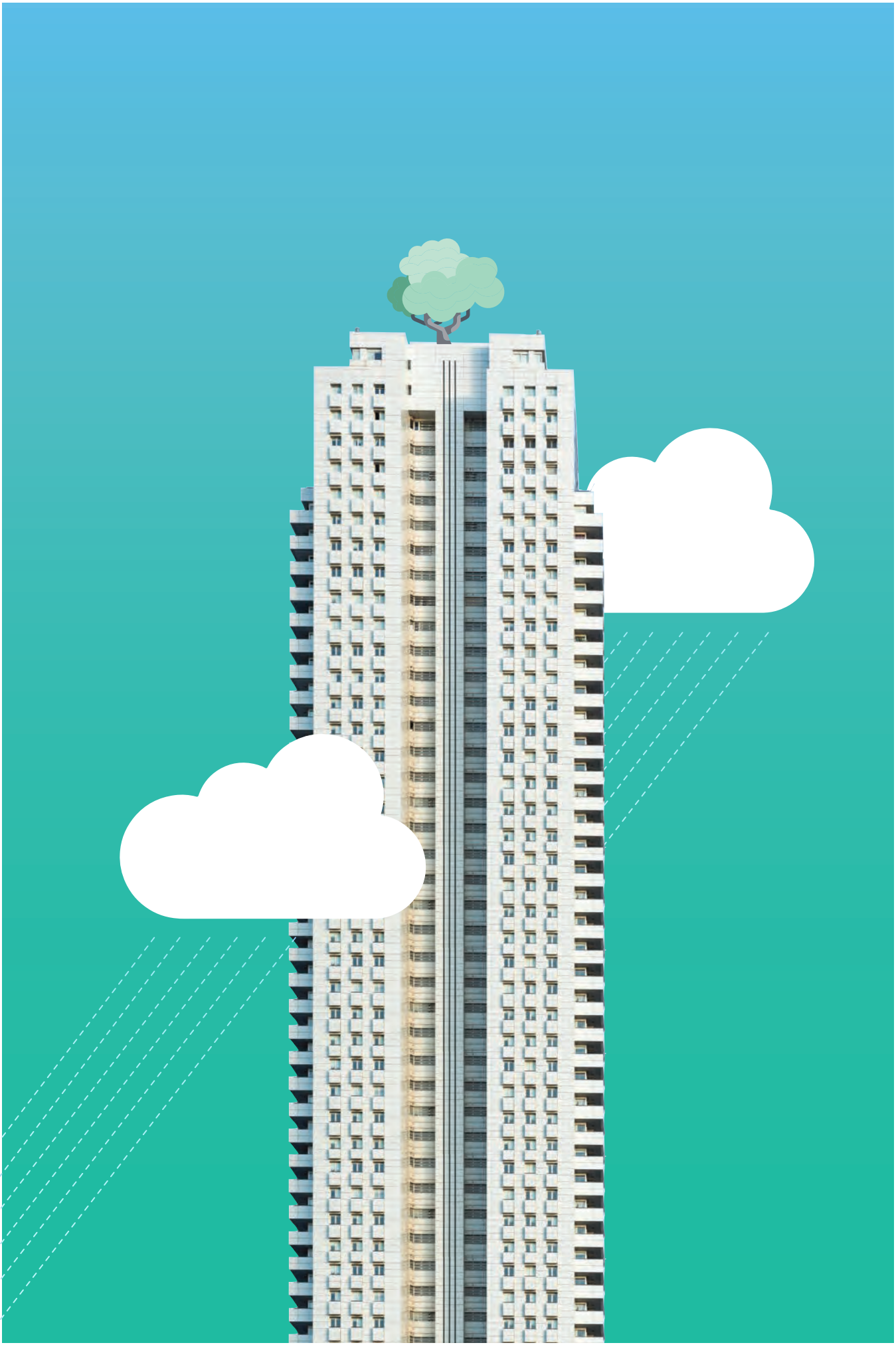
15 themes; 40 departments; over 200 faculty members and affiliates; and countless postdoctoral researchers, graduate and undergraduate students. From a distance, it might be hard to see how all our moving parts function as one entity. But if you take a closer look, you will find the common threads that bind us together as we solve difficult challenges.

You will also see how, regardless of who we are and where we come from, we are united in our love of the unknown.

What does the future of plants look like in the face of global warming?

Plants are synonymous with growth, abundance, and health. In almost all civilizations, they have been viewed as sacred and are venerated as symbols of life and immortality. We are completely dependent on plants; we require them for food, clothing, shelter, fuel, and the oxygen we breathe. Without them, Earth as we know it would not exist. And yet, the very same planet now threatens their survival. →





Over the past few decades it has become obvious that the current increases in atmospheric CO_2 will have lasting effects on our world. Unsurprisingly, the resulting greenhouse effect is warming the atmosphere and increasing the number of droughts. Unlike animals, plants cannot uproot their lives and move to more suitable environments. Therefore, in the face of these new challenges, we have to reconsider how we can help plants adapt in order to keep up with the demands in food supply. Fortunately, scientists are doing just that, and they are discovering that plants are resilient in ways they never imagined.

To understand how remarkable the adaptations are, it is first necessary to understand the problems that plants have to overcome. To do so, Illinois researchers looked at how higher temperatures influence plant growth despite the greater availability of atmospheric CO_2, a key component of photosynthesis. They found that excessive heat can reduce the efficiency of enzymes that drive photosynthesis and can hinder plants' ability to control CO_2 uptake and water loss. For example, Rubisco—the key enzyme that fixes CO_2 into sugars—speeds up as the temperature increases, but it also makes more mistakes. At even higher temperatures, the enzyme loses its structural integrity and becomes ineffective.

How the big city life gives plants an edge

One would assume that in cities where elevated temperatures are common, plants suffer compared to their rural equivalents. It turns out that if, as a plant, you can make it in a big city, you can make it anywhere. In a new report, researchers saw that vegetation in urban areas have stronger drought resistance compared to their rural counterparts.

What could be causing this effect? According to Peng Fu, a former postdoctoral researcher at Illinois, the higher temperatures lengthen the growth season allowing plants to accumulate biomass that helps them deal with the drought. Additionally, the higher CO_2 concentration in cities leads to more vegetation growth further increasing their drought resistance.

Peng Fu taking measurements at the Illinois Energy Farm.

Can plant memory challenge that of an elephant's?

If the adaptation of urban vegetation isn't impressive enough, plants may also have the ability to "remember" how to deal with drought. According to a new study, crops that experience drought conditions or extreme temperatures early on are better able to deal with those same conditions later in their growth cycle.

"What we have seen is if the crop survives an early drought, because of that experience they perform better when a drought occurs very close to harvest," said Fu. "We think that the crops respond to the drought and adapt to it, so when it happens again the crops have already planned for the drought and the impact is lessened."

Looking forward

There are several lessons that researchers have learned from these findings. First, they can transfer genes that are responsible for heat tolerance to vulnerable crops, helping countless farmers. Second, they can build better models for climate change scenarios using the responses of urban vegetation, as cities are already experiencing heightened temperatures. Third, they can continue improving how plants are monitored. For example, researchers have developed satellites that can detect changes in chlorophyll fluorescence in plants, indicating whether a crop is under heat stress. These changes in fluorescence are detectable before the plant shows any outward sign of heat stress, enabling farmers to respond more quickly to crop needs. They are also deploying new imaging and machine-learning tools to discover how plants use water efficiently. The goal is to breed or engineer crops that are better at conserving water without sacrificing yield, according Andrew Leakey, a professor of plant biology and of crop sciences. Together, these measures will hopefully bring us closer to a future where all crops will form oases of abundance in a warmer and drier world.

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Lisa Ainsworth, Dylan Allen, Darshi Banan, Claire Benjamin, Carl Bernacchi, Patrick Brown, Amanda Cavanagh, **Min Choi, Anna Dmitrieva, Gorka Erice, John Ferguson, Samuel Fernandes, Luke Freyfogle, Peng Fu, Deepak Jaiswal, Andrew Leakey (CABBI Director),** Alexander Lipka, **Stephen Long, Dustin Mayfield-Jones,** Justin McGrath, **Katherine Meacham-Hensold,** Caitlin Moore, **Rachel Paul, Charles Pignon, Parthiban Prakash, Peter Schmuker, Rebecca Slattery,** Shaowen Wang, and **Dan Xie, Jiayang (Kevin) Xie**

CABBI, GEGC

Food and Energy Security, Journal of Experimental Botany, Environmental Research Letters, The Journal of Experimental Botany, and *Plant Physiology*

Bill & Melinda Gates Foundation, CABBI, DOE, Foundation for Food & Agriculture Research, Graduate Student Fellows Program, NASA, NSF, U.K. Foreign, Commonwealth & Development Office, University of Illinois, and USDA

傅鹏
Peng Fu

PEOPLE BEHIND THE SCIENCE

Having grown up among the lush rice fields in China, it was inevitable that Peng Fu would become passionate about crops. Throughout the holidays in his childhood, Fu would help his parents, who are both farmers, with their work. He would wake up early in the morning and go into the muddy waters of the paddy fields and plant the rice manually. They would all retire before noon, when it got too hot. "When I was a child I thought about what I could do for my parents. They worked very hard in the fields and I would want to make the manual labor easier and more efficient," Fu said.

Fu grew up in Zhugan, or "bamboo", a misnomer because the village doesn't have any bamboo. The farmers grew rice, wheat, and rapeseeds, from which canola oil is obtained.

The first time he was exposed to a formal education in agricultural practices was in college. "Typically, the college entrance exams are competitive and though I wanted to study agriculture mechanical engineering, I was randomly assigned to a major in geographic information science. When I joined in 2008, it was a new major," Fu said.

The students learned a combination of different subjects: environmental science, ecology, agronomy, computer science, and how to use geospatial techniques to increase agricultural productivity. "We learned how to monitor soil nutrients over time and how to assess the fertility of the land," Fu said. "I had to do a lot of soil analysis and I didn't appreciate that work because it was very tedious; I didn't like the muddy water, and it would take months to get any results. We also learned how to use image data and information from satellites and drones to correlate what we measured in the soil samples. I liked this analysis better."

During his college years, Fu's life at home also changed. "After my graduation, my parents didn't let me help in the fields. Even though I would try to take off my shoes and jump in the water, they would stop me. It was out of love that they didn't want me to suffer in the fields," Fu said. "Instead, I would cook for them and make different types of rice and vegetable dishes."

Spurred by his desire to use his education to help his parents, Fu joined Indiana State University in 2012 for his graduate studies. He developed geospatial algorithms for various applications in agriculture, public health, and the environment. He also compared the air and surface temperatures in cities and in the countryside to illustrate the effects of urbanization on our natural environment.

"We use cities as a natural laboratory to understand how plants respond to global warming," Fu explained. "Cities are already experiencing some of the environmental changes that we project for the future: higher temperatures, higher pollution, and changes in relation to precipitation or humidity. We can integrate those data into different models and try to understand how vegetation responds to those environmental variables."

After his PhD, Fu had to decide whether he wanted to accept a job in Britain working on geospatial algorithms related to land surface temperature or whether he wanted to come to Illinois. "I chose Illinois because I wanted to learn about photosynthesis and there are many great scientists here who study that," Fu said. "The last time I learned photosynthesis was as a high school student. At the University of Illinois, I have learned that there's a lot we can do to improve photosynthesis and I wanted to sharpen my geospatial skills and find a way to do collaborative work."

Fu's experience in Illinois also enriched his social life. "When I first came to the US, it was a big culture shock. For example, in China we don't typically go to bars after work and sometimes I felt lost in the conversation because I like talking about random things. I focused on my research instead and stayed mostly alone," Fu said.

"That changed when I moved to Illinois. My supervisor Carl Bernacchi taught me how to work with people and become more productive. My lab ended up being like my family."

Fu recently accepted an assistant professor position at Harrisburg University in Pennsylvania. He will be looking at how geospatial techniques can be used to quantify carbon dioxide emissions and will help address issues related to climate change, energy, and agriculture. "I want to quantify the benefits of different agricultural practices in terms of their carbon emissions. It is beneficial for mitigating climate change," Fu said.

"We're also concerned about food security and what we do can help achieve the co-sustainability of agriculture and the environment."

When asked about his dream lab, Fu's eyes light up. In addition to being excited about the research, Fu is also enthusiastic about setting up a great work environment.

"In Carl's lab we worked together and learned from each other. I want to have graduate students and postdoctoral researchers who share my vision. I want to treat them like colleagues, the way I was treated by Carl."

Fu's biggest challenge is still dealing with his identity as an immigrant. "It's difficult being the eldest son in my family. My parents are getting older and I'm supposed to take care of them.

“努力加汗水，才会有收获。”

“My mom always said when you want something, you need to work hard and go get it.”

PENG FU

ASSISTANT PROFESSOR AT HARRISBURG UNIVERSITY

FORMER POSTDOCTORAL RESEARCHER AT THE UNIVERSITY OF ILLINOIS

Peng’s labmates

It will be challenging in the next few years because there will be a lot of pressure coming from both my family and my job,” Fu said. “It’s also hard to promote my research. Even after ten years language is still a barrier and sometimes it’s still a challenge for me to express my research ideas clearly to my collaborators.”

However, Fu is slowly learning about American culture through his children. “I have two sons who are five-and-a-half years and seven months old. I am learning new things about school in the US as the older one goes to kindergarten,” Fu said.

In his spare time, Fu loves being around his children. “I take them to parks and teach my older son how to play soccer and basketball,” Fu said. “In China the grandparents typically help in taking care of the kids, but because of the pandemic no one came to help us. Although I get help from the lab, I like caring for the kids so that my wife can get some rest,” he added with a smile.

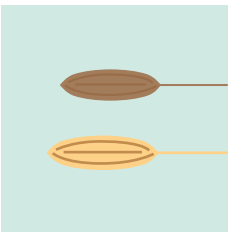
Comparing photosynthetic differences between wild and domesticated rice

Wild rice is typically weed-like and taller than cultivated rice. While these features shade out competitors in the wild, they are unfavorable in an agricultural setting. Through domestication, many rice varieties have been selected to be short with erect leaves, which allows better light distribution. Despite these improvements, the distribution is uneven and is affected by changes in cloud cover.

During the switch from low to high light, leaves start taking up more CO_2 for photosynthesis, a process called photosynthetic induction. Since the adjustment is not immediate, it lowers photosynthetic performance over the course of a day. Conversely, during the switch from high to low light, the stomata—minute openings in the leaves through which CO_2 and water vapor move—can close too slowly, leading to unnecessary water loss.

According to Liana Acevedo-Siaca, a former graduate student in the Long lab, the photosynthetic induction was a lot faster in wild rice whereas the domesticated species was faster at closing their stomata, leading to less water loss.

"We were interested to know whether the domestication of rice inadvertently improved its photosynthetic efficiency. Alternatively, if the breeding process was detrimental to particular characteristics, maybe we can go back to wild rice and introduce those traits into domesticated rice," said Stephen Long, the Ikenberry Endowed University Chair of Crop Sciences and Plant Biology.



go.igb.illinois.edu/wildrice

Liana Acevedo-Siaca
Stephen Long

IGB
BSD
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Food Energy and Security

Bill and Melinda Gates Foundation
Foundation for Food and Agriculture Research
UK Foreign, Commonwealth & Development Office

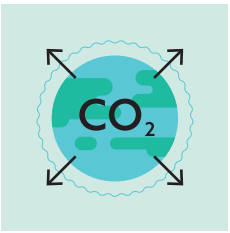
C4 Rice Center at the International Rice Research Institute, Los Baños, Philippines

Improved ag tech could help food security, climate change emergencies

Scientists have proposed a range of technological options for sustainable, productive, and resilient agriculture, providing multiple ways to remove CO_2 from the atmosphere and helping to directly mitigate climate change.

The team, led by Ikenberry Chair Professor of Plant Biology and Crop Sciences Stephen Long and Professor David Beerling, Director of the Leverhulme Centre for Climate Change Mitigation at the University of Sheffield, proposed transformations of land management and agronomic practices, including innovative amendments to soils, crop management, and land use, to increase the removal of CO_2 from the atmosphere. Long has dual appointments at the University of Illinois and Lancaster University.

The research proposes that innovative technologies and new crop varieties, with increased photosynthesis and resource-use-efficiency, can maximally exploit agronomic



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Stephen Long

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practices and soil amendments to enhance carbon storage as well as improve food yield.

Agricultural reforms have often focused on the trade-offs between climate change mitigation and food production. The new research offers a different perspective on how agriculture can deliver global food security through increased productivity and at the same time make a major contribution to climate change mitigation through capture of atmospheric CO_2.

"Sustainable yield increases in crops made possible by genomic and genetic engineering technologies could create more space for alternative land uses that further increase carbon storage, including managed afforestation, rewilding or biomass crops as feedstocks for biodegradable materials and bioenergy. But careful analysis is needed to discover which approach can deliver the greatest climate change mitigation in the shortest time," said Long.

Bioprocess developed for converting plant materials into valuable chemicals

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Yong-Su Jin
Soo Rin Kim
Stephan Lane
Jae Won Lee
Liang Sun
Ziqiao Sun
Sangdo Yook

BSD
CABBI
MME

Nature Communications

CABBI

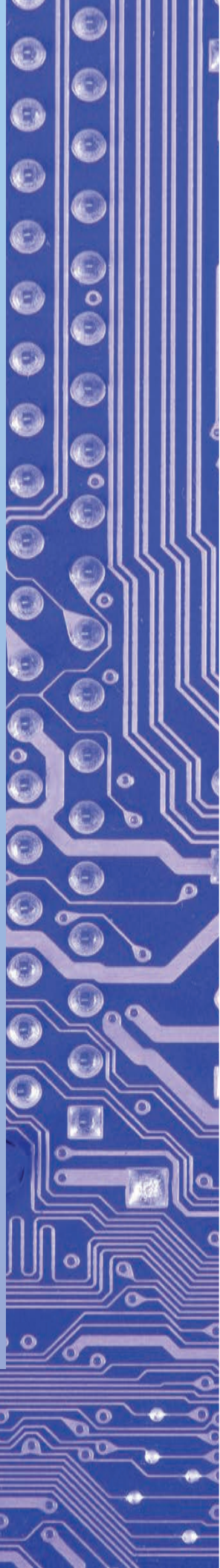
Lignocellulose, the woody material that gives plant cells their structure, is the most abundant raw material on Earth and has long been viewed as a source of renewable energy. It contains acetate and the sugars glucose and xylose, all of which are released during decomposition.

In a new paper, researchers described a viable method for overcoming one of the major hurdles impeding the commercialization of lignocellulosic biofuels—the toxicity of acetate to fermenting microbes such as yeast.

When glucose and acetate are provided together, the yeast rapidly convert glucose into ethanol, decreasing the pH and inhibiting acetate consumption, leading to toxic conditions. However, when xylose was provided with acetate, the two carbon sources formed synergies that promoted efficient metabolism of both compounds, according to food science and human nutrition professor Yong-Su Jin who led the research with a former graduate student.

When they analyzed yeast's gene expression by RNA sequencing, they found that key genes involved in acetate uptake and metabolism were dramatically upregulated by xylose compared with glucose. Co-utilization of acetate and xylose also increased the yeast's supply of acetyl-CoA, a precursor molecule of lipids.

"We hope that in 50 or 100 years, we will depend mainly on these renewable and abundant feedstocks to produce the energy and the materials we need for our daily life," Sun said.



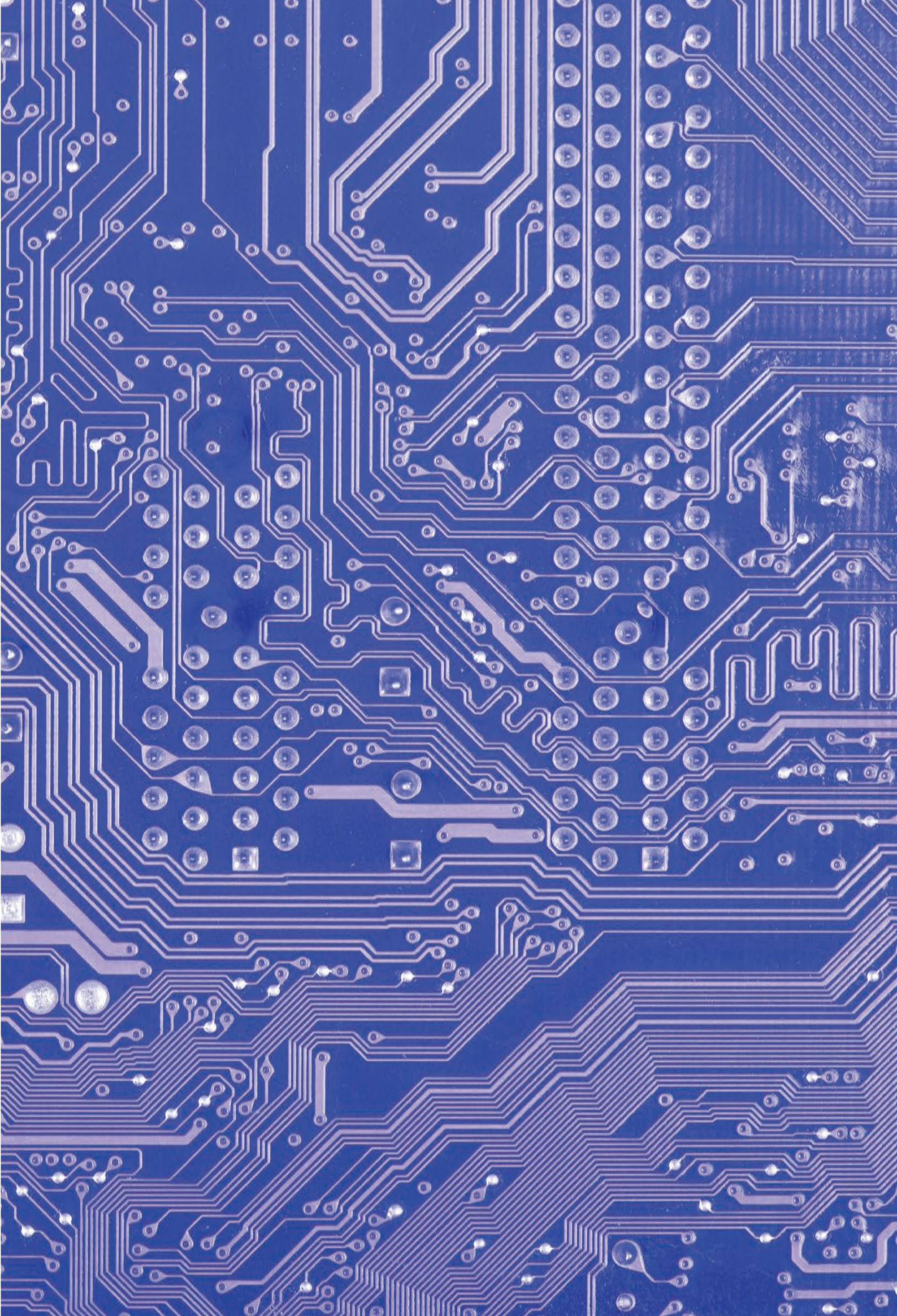
Smaller, better, faster, stronger diagnostics

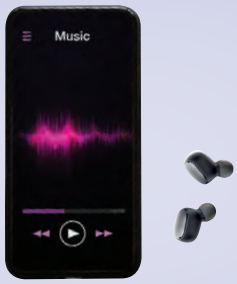
Over the past few decades, technology has progressed in leaps and bounds, accompanied by a drive to create smaller gadgets. →

Detecting complex disease pathways using small DNA mutations

Creating cost-efficient antibody tests

Smaller is better for photonic microscopes




Music

Speakers have shrunk from boomboxes to the size of an AA battery; phones have been transformed from large, sedentary appliances to palm-sized devices that make cameras, calculators, maps, and flashlights redundant; and car engine sizes have been more than halved from 500-pound behemoths. Unsurprisingly, medical technology and diagnostics have also followed a similar trend, with an emphasis on sensitivity, speed, and cost.

Detecting complex disease pathways using small DNA mutations

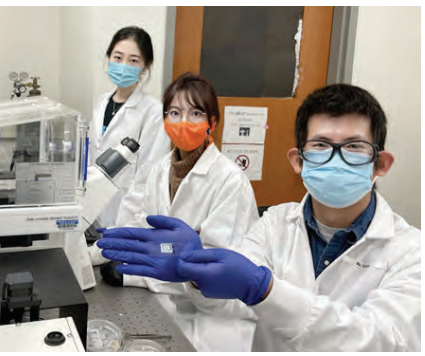
Cellular pathways, like telecommunication networks, are highly interconnected. A single dysfunctional protein can cause a cascade of events that lead to disease. For instance, a molecule linked to bone loss can also appear in the same pathway as certain types of cancer. By studying these interactions, we can better understand what molecules to target. But how does one untangle such complicated pathways?

Xiaoman Xie, along with Saurabh Sinha, developed VarSAn to detect disease pathways using single-nucleotide polymorphisms.

In 2021, researchers developed a new computational tool that can identify pathways related to diseases, including breast and prostate cancer, using single-nucleotide polymorphisms. SNPs, which refer to mutations in a person's DNA, are the most common type of genetic variation among people. The researchers hope that the tool can help them discover new pathways that have been previously overlooked.

The tool, called VarSAn (Variant Set Annotator, pronounced 'version'), uses SNPs that have been identified by sequencing studies as being disease-related, to predict which pathways may be perturbed by these SNPs.

"The underlying computation is similar to how Google uses an algorithm to identify the right web pages for searches. These types of algorithms are applicable in biology as well to understand genetic variation," said Saurabh Sinha, a professor of computer science. "Additionally, 90% of the disease-related mutations are in parts of the DNA that do not code for proteins and using this type of approach will be useful for future work."



A team at the Holonyak Micro & Nanotechnology Lab displays the new COVID-19 antibody test.

A PRAM image in which each black dot represents one detected COVID-19 antibody molecule.

Creating cost-efficient antibody tests

The spread of COVID-19 quickly made it obvious that we needed vaccines to combat the disease. However, a key question haunted all the vaccine developers: How effective were their products? Members of the Cunningham group Congnyu Che, Weijing Wang, Nantao Li, and Bin Zhao developed a COVID-19 antibody test to answer that question.

When COVID-19 was threatening to become a global crisis in early 2020, the group was already working on a project to develop a "flu chip" that would rapidly determine the most likely cause of a fever by measuring several proteins within a droplet of blood. They decided to pivot their efforts to detect COVID-19 antibodies instead. Their effort created a simple, 15-minute test, which cost less than $2 per test and could be used with a desktop detection system that is suitable for clinics and physician offices, according to Zhao.

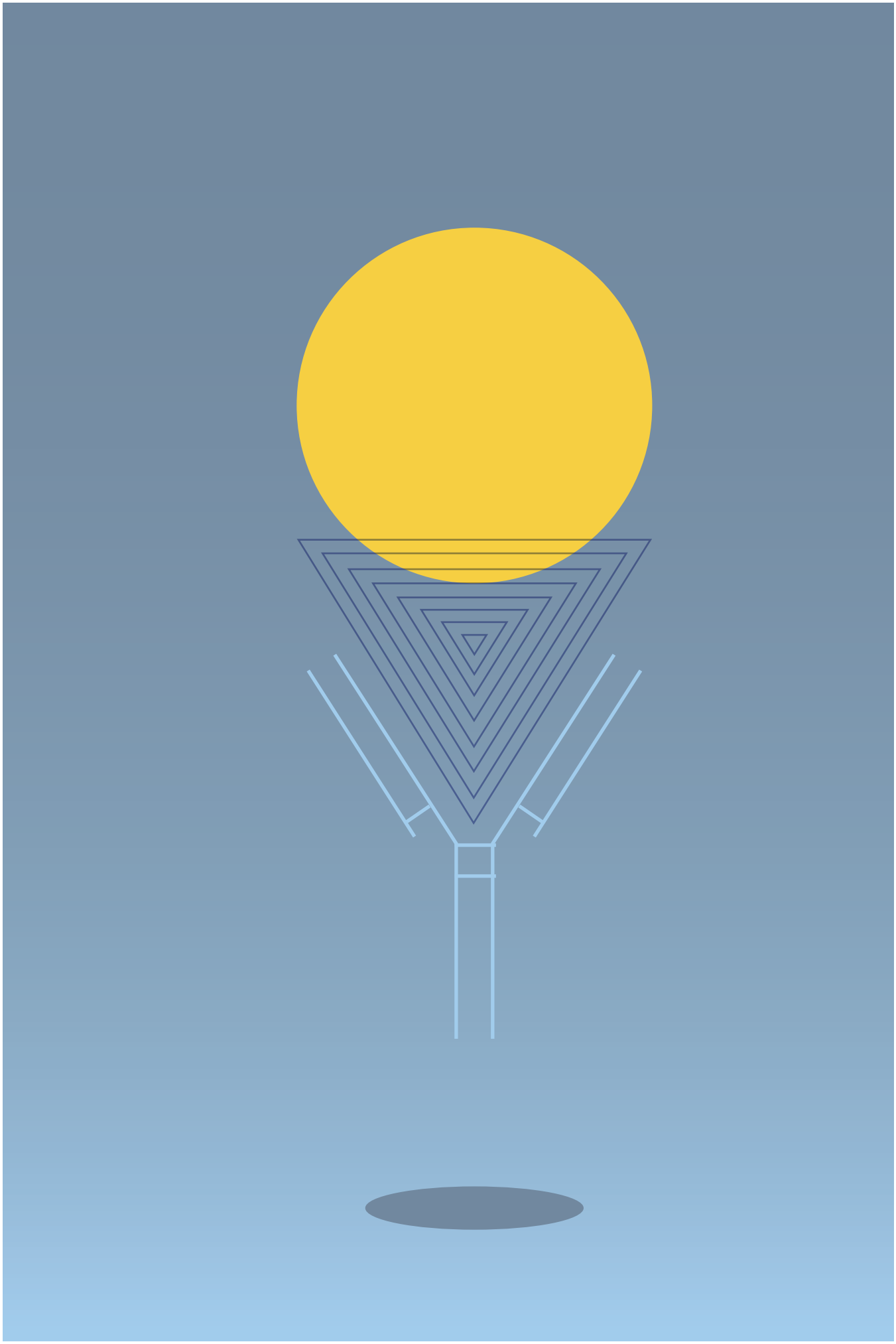
Serological (detected by blood sample) antibody testing is now widely recognized as an important diagnostic tool for combating the COVID-19 pandemic. Studies have shown that measurement of SARS-CoV-2 specific antibodies may be helpful for the diagnosis of suspected patients with negative RT-PCR results and for the identification of asymptomatic infections—a cause for concern as vaccinations may lessen or eliminate symptoms as well as prevent infection.

"Our developed method is not only rapid and simple, but also highly sensitive and quantitative. It also requires only a fingerstick quantity of blood (~ 4 µL)," said Li. "The method that we used to detect COVID-19 antibodies can also be adapted to detect other molecules, such as antibodies to other viral pathogens, biomarkers for cardiac disease, and for cancer."

This highly sensitive, fast, and low-cost test demonstrates great potential for wide applications in diverse working environments. The test is simple enough to be performed at schools, health clinics, pharmacies, and parts of the world where diagnostic laboratories are unavailable.

Smaller is better for photonic microscopes

The Cunningham group has also made advances in creating better techniques for point-of-care-diagnostics using nanostructures. For several years they have been developing microscopes that use photonic crystal biosensors—nanostructured glass surfaces that brightly reflect only one wavelength of light. Although the original photonic crystal microscope was very versatile, it was the size of a ping pong



table, making it inconvenient to transport, according to Brian Cunningham, the Intel Alumni Endowed Chair of Electrical and Computer Engineering.

"We wanted to build a portable instrument that had the same detection capabilities. The new one we built can easily fit on a desk and costs around $7,000, compared to the non-portable microscope, which costs $200,000," Cunningham said.

The larger photonic crystal microscope provided a strong contrast by counting surface-attached gold nanoparticles, a feature that the portable version also shares. The photonic crystals act like a mirror, but only for the color red. Since the gold nanoparticles are non-reflective, they show up as dark spots. The microscopes can therefore be used to detect biomarkers that are linked to the gold nanoparticles. The portable version uses a red LED light, which gets reflected off the photonic crystal, and the image is captured by a webcam.

The microscope was used to detect specific microRNAs—small, single-stranded, non-coding RNAs—that are associated with prostate cancer. Each gold nanoparticle was attached to a single-stranded piece of DNA, called the probe, which in turn was attached to pieces of single-stranded protector DNA. If the target miRNA sequence was present in the sample, it would displace the protector DNA, which would cause the nanoparticle to bind to the photonic crystal, according to Shreya Ghosh, a previous postdoctoral researcher in the Cunningham lab.

Since almost every cancer has miRNAs associated with it, the microscope can, in theory, be used to detect different cancer types. The group is currently seeking to establish a Center for Enhanced Biosensor Microscopy at the IGB, where they will be able to train researchers throughout the academic research community to use these instruments to detect any type of biomarker.

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Congnyu Che, **Brian Cunningham,** Erika Falkiewicz, Xiyu Ge, Shreya Ghosh, Matthew Kendzior, Nantao Li, Liudmila Mainzer, Ege Onal, Michael Rathslag, **Saurabh Sinha,** Xiaoman Xie, Yanyu Xiong, Weijing Wang, Bin Zhao

BSD, CABBI, CGD, GNDP, GSP, MMG

Biomedical Optics Express, Nucleic Acids Research, Talanta

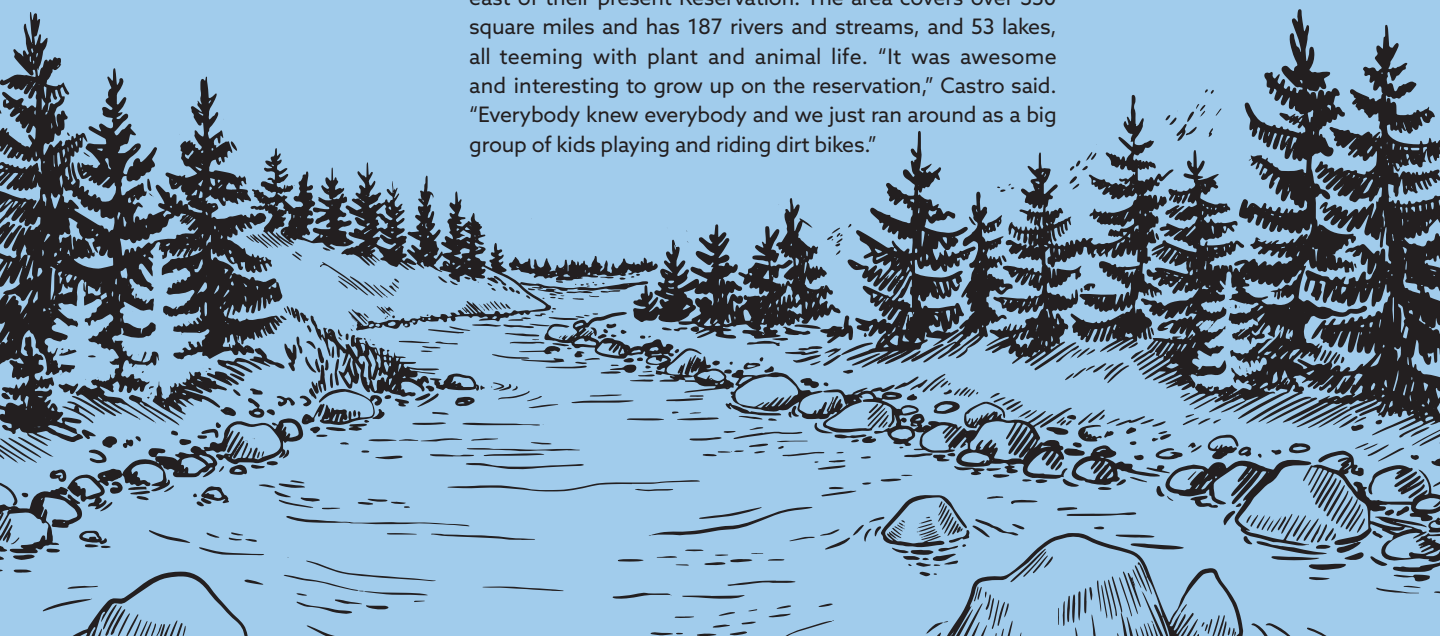
Mayo Clinic and Illinois Strategic Alliance for Technology-Based Healthcare, Mayo Clinic Center for Individualized Medicine, NIH, University of Illinois, Zhejiang University ZJU-Illinois Joint Research Center

Daniel Castro

PEOPLE BEHIND THE SCIENCE

Creating concoctions is a great way to stimulate children of every age. By combining ingredients, they can make new substances to play with and learn about chemical reactions. They could also learn how to become better cooks or better chemists, or in the case of Daniel Castro, both.

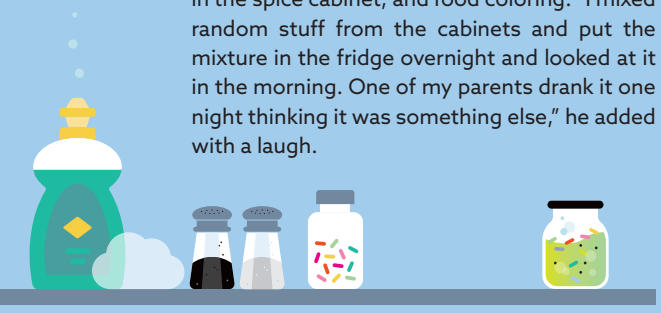
Castro was born on the Menominee Indian reservation in Wisconsin. The Tribe's history is unique because their origin begins at the mouth of the Menominee River, just 60 miles east of their present Reservation. The area covers over 350 square miles and has 187 rivers and streams, and 53 lakes, all teeming with plant and animal life. "It was awesome and interesting to grow up on the reservation," Castro said. "Everybody knew everybody and we just ran around as a big group of kids playing and riding dirt bikes."



After a few years Castro moved to Green Bay, Wisconsin. "Although we were surrounded by more people, we had lesser interactions with them and it felt like we were just passing by. I missed how everyone took care of each other," he said.

During his childhood, Castro was captivated by how food impacts our bodies. "It's fascinating how a seemingly inert substance can have such a large impact on our mood, our thoughts, and our overall physiology. That interest pushed me into science," Castro said.

Castro's interest resulted in a variety of concoctions that, much to his parent's despair, ended up in the refrigerator. His mixtures included dish soap with pepper, or anything else in the spice cabinet, and food coloring. "I mixed random stuff from the cabinets and put the mixture in the fridge overnight and looked at it in the morning. One of my parents drank it one night thinking it was something else," he added with a laugh.



Spurred by his love of chemistry, Castro joined University of Wisconsin-Stevens Point where he majored in biochemistry. "I chose it over chemistry because there was less math involved," he said with a smile. "Also, it had the balance between learning about the human body and the chemistry aspect that I really enjoyed." He soon realized he liked the analytical side of chemistry. Although such work is sometimes considered tedious, Castro enjoyed devoting his time and patience to his projects and watching it all come together.

After he graduated in 2015, he joined a food safety lab in Marshfield, a food testing company. He was in charge of testing the dairy products for microorganisms, including *Listeria monocytogenes, Escherichia coli*, and *Salmonella enterica,* that can cause food-borne infections. He continued working at the same company as a chemistry research assistant using analytical instruments to improve the company's quality control procedures. That's where he met his new obsession: mass spectrometry.

"I just fell in love and I've been doing it for seven years now and I'll probably do it for the rest of my life," Castro said. Mass spectrometry is a technique that is used to identify chemical compounds on the basis of their molecular weight, allowing the determination of their chemical structure and properties. "It's fascinating that we can use it to measure ions, something that we cannot see," he explained.

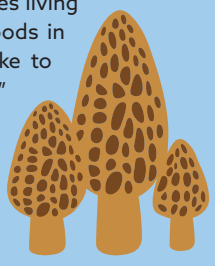
Castro joined the Department of Biochemistry in 2018 where, unsurprisingly, he joined the Sweedler group to learn more about mass spectrometry. He works on developing new mass spectrometry approaches to measure individual cells and their chemical contents in a high-throughput fashion.

"I really like that I get to use a state-of-the-art piece of equipment," Castro said. "I like the creativity and the freedom I have to develop new approaches to answer certain questions. It allows me to think critically and independently. It's also a unique opportunity because I can try things not knowing if they'll work. Even though making the new measurements involves a lot of failure, it's incredible when it works."

In his spare time Castro enjoys cooking, a reflection of his love for chemistry. His favorite culinary season is spring because he goes hunting for morel mushrooms, which have a distinctive honeycomb appearance. "You can only get them for a month. I usually immediately eat the first ones I find because they're a delicacy and they have an earthy taste—like a truffle-y breakfast sausage," he said. Although these are prized by gourmet cooks, particularly in Catalan and French cuisine, Castro's efforts are nothing to be sniffed at. He uses the sun-dried mushrooms to make frittatas with duck eggs and goat cheese.

His comfort food, though, is much simpler. "My favorite food is butter noodles with some Parmesan," he said. When asked whether he still tries odd combinations of foods, Castro smiled. "I put cake in a bowl and pour milk on top when I eat it."

When he's not tinkering with recipes, Castro enjoys mountain biking, snowboarding, camping, and kayaking. Although he likes living in Champaign, he misses the woods in Wisconsin. "I would ultimately like to settle in a city like Bend, Oregon," he said. "I'm excited to own a little piece of land where I can enjoy myself and have the space to grow food."



“Perfect mundo.”

Castro loved saying it whenever he landed a trick on his skateboard as a kid.

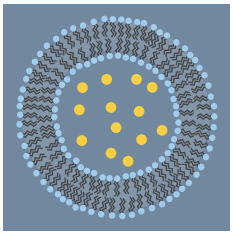
DANIEL CASTRO

GRADUATE STUDENT

DEPARTMENT OF BIOCHEMISTRY

Daniel Castro

Analytical technique helps spot subtle differences in subcellular chemistry



Researchers can now rapidly isolate and chemically characterize individual organelles within cells. The new technique tests the limits of analytical chemistry and rapidly reveals the chemical composition of organelles that control biological growth, development and disease. The study was led by chemistry professor Jonathan Sweedler.

The new approach locates and isolates individual organelles using light microscopy, then chemically analyzes them via MALDI MS, or matrix-assisted laser desorption/ionization mass spectrometry. The entire process takes an hour—a task that could take human analysts years to complete. For this study, the team focused on the cell's vesicles—both dense-core and lucent varieties—collected from sea slugs, which are a commonly used neuroscience study model. Vesicles were selected as the organelle of interest because they are involved in chemical cell-to-cell signaling.

The researchers said they are not the first to characterize organelles chemically. But using their automated targeting and chemical analysis approach is faster and more accurate, and assures that they analyze exactly what they intend. This way, they can determine the chemical makeup of a single organelle.

"Our new workflow can help the scientific community complete the 'parts list' of the organelles found within cells," graduate student Daniel Castro said. "Having that list will help us determine if something is missing or extra within the organelles, helping us spot subtle changes and study how those changes correlate to diseases such cancer and those related to the brain and mental health."

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Daniel Castro
Elena Romanova
Stanislav Rubakhin
Jonathan Sweedler
Yuxuan Richard Xie

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CABBI
MMG

Nature Methods

NIH

Deep-learning algorithm aims to accelerate protein engineering

Proteins are the molecular machines of all living cells and have been exploited for use in many applications, including therapeutics and industrial catalysts. To overcome the limitations of naturally occurring proteins, protein engineering is used to improve protein characteristics. In a new study, researchers demonstrate a machine learning algorithm that accelerates the protein engineering process.

Machine learning algorithms assist in protein engineering by reducing the experimental burden of methods such as directed evolution, which involves multiple rounds of mu-

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Hantian Ding
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Wesley Wei Qian
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Huimin Zhao (Theme Leader)

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Nature Communications

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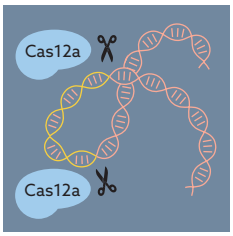
tagenesis and high-throughput screening. Although many machine learning algorithms exist, few incorporate the evolutionary history of the target protein. This is where ECNet (evolutionary context-integrated neural network), a deep-learning algorithm, comes in.

In a benchmark study, the researchers showed ECNet outperforming current methods on several deep mutagenesis datasets. As a follow-up, ECNet was used to engineer TEM-1 ß-lactamase—an enzyme that confers resistance to ß-lactam antibiotics—and identify variants that had improved fitness and therefore, were more resistant to ampicillin.

"We are combining all the proteins in the database with the specific evolutionary history of the target protein to improve the prediction efficiency," said Steven L. Miller Chair Professor of Chemical and Biomolecular Engineering Huimin Zhao. "This algorithm is still a work in progress, but it's an overall improvement on what's already known in the literature."



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Direct cloning method CAPTUREs novel microbial natural products

Microorganisms possess natural product biosynthetic gene clusters (BGCs) that may harbor unique bioactivities for use in drug development and agricultural applications. However, many uncharacterized microbial BGCs remain inaccessible. Researchers at Illinois have now developed a direct cloning method that aims to accelerate large-scale discovery of novel natural products.

Named Cas12a assisted precise targeted cloning using *in vivo* Cre-lox recombination (CAPTURE), the method allows for direct cloning of large genomic fragments, including those with high-GC content or sequence repeats. Where existing direct cloning methods fail to effectively clone natural product BGCs of this nature, CAPTURE excels.

Researchers first characterized the efficiency and robustness of CAPTURE by cloning 47 natural product BGCs from both *Actinomycetes* and *Bacilli*. After demonstrating nearly 100% efficiency of CAPTURE, 43 uncharacterized natural product BGCs from 14 *Streptomyces* and three *Bacillus* species were cloned and heterologously expressed. The produced compounds were purified and determined as 15 novel natural products, including four that exhibited antimicrobial activity against methicillin-resistant *Staphylococcus aureus*, vancomycin-resistant *Enterococcus*, and *Bacillus anthracis*.

The researchers plan to characterize these compounds for other bioactivities such as antiparasitic and anticancer properties. Preliminary results are already showing anticancer properties for some of the compounds.

"Due to its exceptional robustness and efficiency, CAPTURE will likely become the method of choice for direct cloning of large DNA molecules such as natural product BGCs from genomic or metagenomic DNA for various basic and applied biological applications," said Steven L. Miller Chair Professor of Chemical and Biomolecular Engineering Huimin Zhao.

How do microbes choose from a "menu" of food?

Microbial communities often contain several species that coexist even though they share similar metabolic abilities. To answer how they do so, researchers have developed a new computational model.

Many microbes grow diauxically—they consume the available food resources one at a time instead of simultaneously. Each species has a particular order of preferences, ranging from most preferred to least preferred. Importantly, this list differs among the different microbes.

The researchers modeled the assembly of a microbial community in serial dilution cultures, where the bacteria are allowed to grow up on a fresh batch of nutrients for a certain time before they are diluted again. The researchers first assumed that a single species could grow on four food resources, growing on its most preferred resource until it runs out and then switching to the next one. After all the resources are depleted, a fraction of the bacteria was transferred to a fresh batch of resources, a randomly chosen second species was introduced, and the researchers modeled the resulting resource depletion. Across many such simulations, the set of microbes in the final community had complementary resource preferences.

"It's very easy to make a big, complicated model. Our philosophy is to add one property at a time, such as diauxie or cross feeding, and understand what is going on at every step. That way you gradually get better at understanding complex, real-world systems," said Sergei Maslov, a professor of bioengineering and Bliss faculty scholar.

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Veronika Dubinkina
Ashish B. George
Sergei Maslov
Tong Wang
Zihan Wang

IGB

BCXT
CABBI

Nature Communications

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Jacob Sherkow

GSP

Journal of the American Medical Association

Use patent law to curb unethical human-genome editing

A new paper co-written by a Illinois scholar who studies the legal and ethical implications of advanced biotechnologies outlines an unexplored tool to regulate the medically and ethically dubious practice of heritable human-genome editing: patent law.

Applied judiciously, patent law could create an "ethical thicket" around human genome editing that ultimately discourages access to "germline editing"—that is, changing sperm and egg to create designer children—in more permissive countries, said Jacob Sherkow, a professor of law.

The World Health Organization has explored international governance tools for human genome engineering, but as long as individual countries are allowed to set and enforce their own policies, the possibility of people engaging in medical tourism to other countries to circumvent domestic prohibitions remains a risk, the authors said.

Even though patents are only enforceable in whatever country they're granted, using patent law as an enforcement mechanism would potentially allow owners to go to court "to stop someone else from using a piece of technology in a way that they don't like," Sherkow said. It could be especially important for countries where patent laws and regulatory systems surrounding gene-editing technologies diverge.

"It's not a complete solution by any means, as it relies on private interests to police the social harms of a private activity," Sherkow said. "But this is a particularly important moment to consider ethical governance by patent, and we think it's a pretty significant arrow in the regulatory quiver."

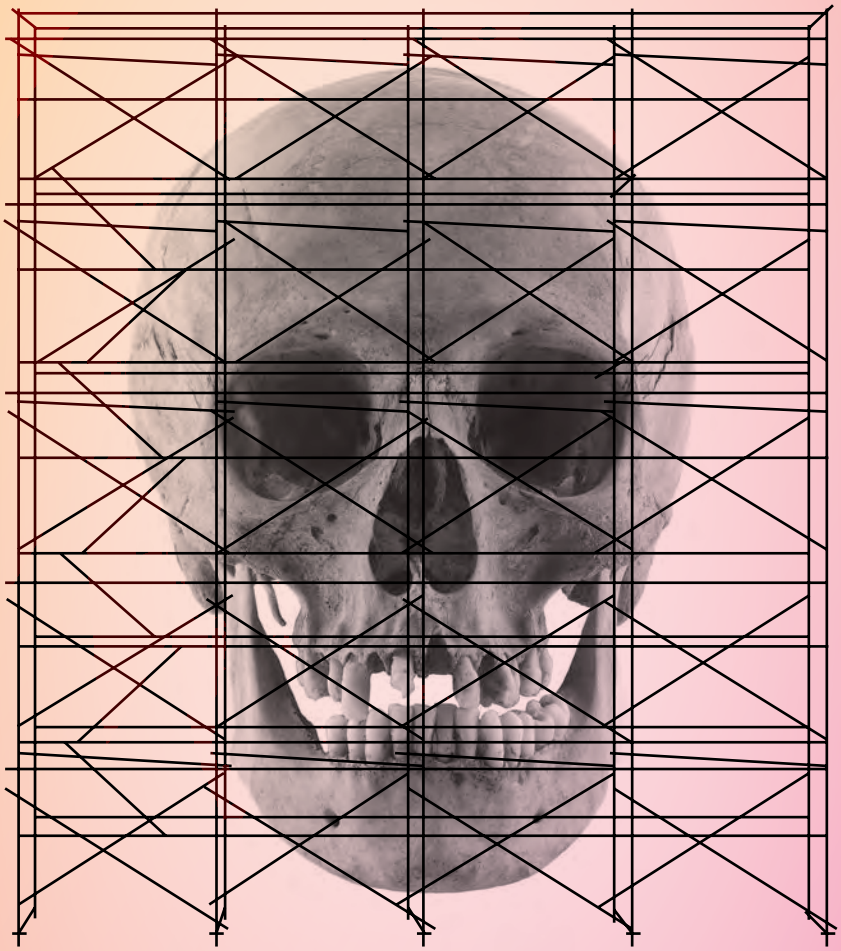
Developing new therapies for old problems

Before the 1800s, minor illnesses, such as colds, were accepted as a way of life. Broken or fractured bones were set using clay materials, a technique that was developed by observing animal behavior. Serious and disabling diseases, however, were considered to be supernatural, resulting from demons, spells, or offended gods. The treatment was to use counter spells and potions. Unsurprisingly, the first "medicine men" were witch doctors who peddled talismans. →

Rebuilding bones with new materials

Harnessing the power of hormones

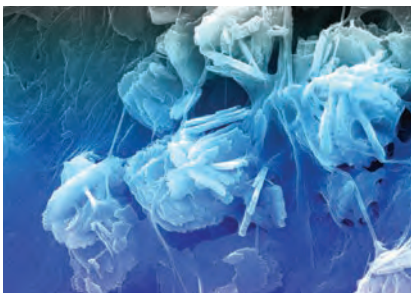
Developing new weapons to target cancer



Modern medicine has come a long way since these mystical cures. Firmly grounded in science, researchers have made many advances, enabling doctors to cure diseases and save lives. Since the 1800s, the life expectancy in the US has doubled from 39 years to 79 years. As scientists continue to invent new treatments, it is important to recognize how far we've come—and how much still needs to be done.

Rebuilding bones with new materials

One of the most powerful non-verbal means of communication lies in your face, which make more than 10,000 expressions. But what happens when injuries, caused by sports or vehicle accidents, damage the bones in our faces and skulls? Repairing such defects is complicated because different types of cells need to interact with each other. These defects are also usually irregularly shaped, requiring biomaterials for reconstruction.



Electron microscope image of the mineralized collagen scaffold showing the mineral crystals and collagen fibers. The color has been added by the researchers.

In a new study, researchers adapted a collagen biomaterial to include one of three different types of sugar compounds found in the bone tissue microenvironment: chondroitin-4-sulfate, chondroitin-6-sulfate, and heparin. They investigated how these compounds influenced bone regeneration. They found that chondroitin-6-sulfate scaffolds led to the greatest amount of blood vessel development.

Although it is unclear how the scaffold material contributes to developmental differences, the discovery can help scientists develop biomaterials that can aid in repairing bone defects.

Harnessing the power of hormones

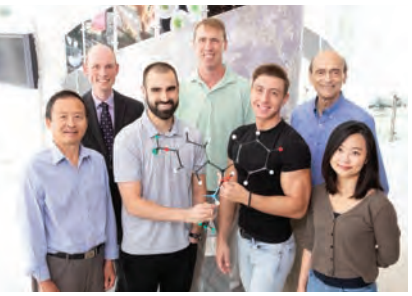
Our body is a veritable metropolis, where hormones zip through the blood carrying messages to our organs and tissues. They affect our emotions, blood pressure, sleep, and how we break down food. Any changes in their levels can result in disease. For example, postmenopausal women have an increased risk of non-alcoholic fatty liver disease due to loss of estrogen from metabolic changes. Unfortunately, a high-fat diet further exacerbates the condition. To deal with this problem, doctors have

Zeynep Madak-Erdogan, an associate professor in food science and human nutrition.

relied on hormone replacement therapy (HRT). Although it is effective, it increases the risk of breast and uterine cancers and cardiovascular disease.

A research team has identified novel estrogen compounds, pathway preferential estrogens, which are structurally estrogens, and provide benefits similar to HRT without the risk factors. The researchers explored the effects of these compounds on liver health in mice. They placed the mice on a high-fat diet and treated one group with HRT, and another group with pathway preferential estrogens. After observing the mice for six weeks, they collected liver tissues for analysis.

"There was an increase in the generation of new mitochondria with pathway preferential estrogens. Mitochondria is a powerhouse, and you need healthy new mitochondria so your cells can continue functioning," said Zeynep Madak-Erdogan, an associate professor in food science and human nutrition. Hopefully, this new treatment strategy will be a safer alternative to HRT in improving postmenopausal health.



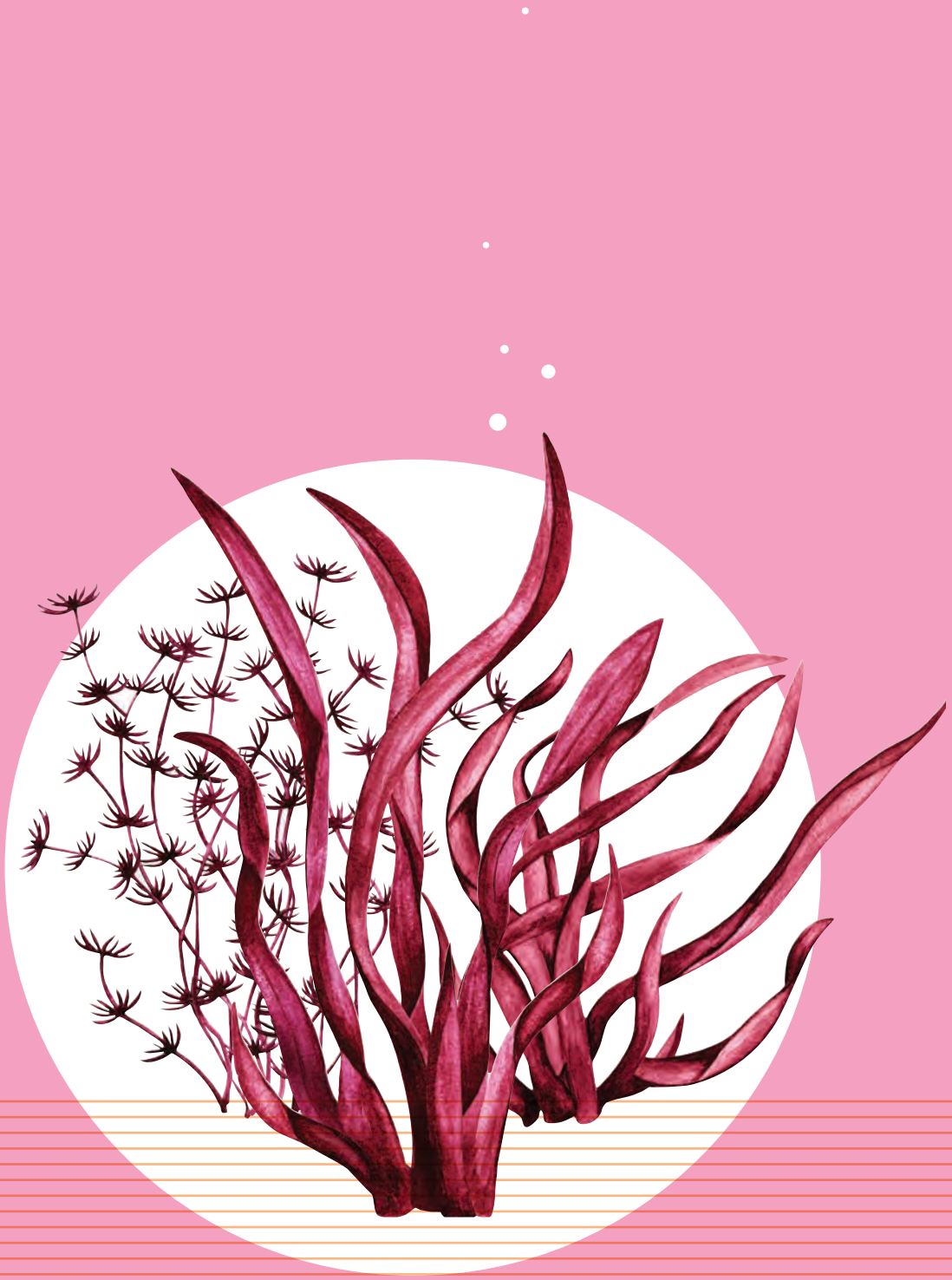
Researchers discovered a small molecule, ErSO, that eradicates breast cancers in mice by targeting a pathway that protects cancer cells. From front left, Chengjian Mao, Matthew Boudreau, Darjan Duraki and Ji Eun Kim. In the back row, from left, Erik Nelson, Paul Hergenrother and David Shapiro.

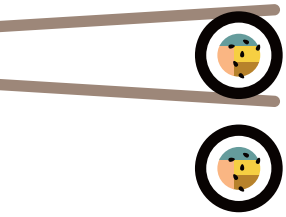
Developing new weapons to target cancer

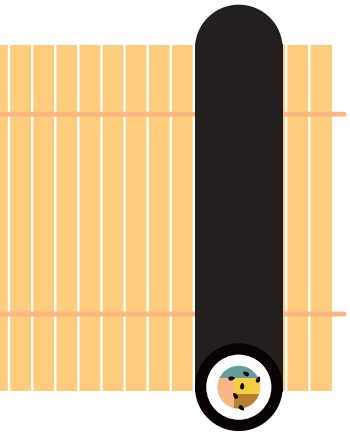
In the past 250 years, researchers have made several discoveries that have helped in the battle against cancer, a thousand-year-old disease. Cancer continues to be a formidable opponent, increasing the need for new treatment methods. Amazingly, a team at the IGB has developed a drug called ErSO that quickly shrinks even large tumors to undetectable levels.

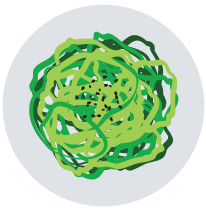
ErSO was discovered in 2021, and it quickly became obvious how powerful it is. When the researchers tested the drug in mice models of human estrogen-receptor-positive breast cancers and their metastases in the bone, brain, liver, and lungs, the drug killed 95-100% of the cancer cells. Impressively, many of the breast cancers shrank by more than 99% in just three days.

ErSO works by binding to the estrogen receptor, upregulating the anticipatory Unfolded Protein Response, which kills cancer cells. About 75% of breast cancers are estrogen-receptor positive, making ErSO a potent drug. Although it still has to be tested in clinical trials, the initial results could finally herald the dawn of a new line of cancer therapeutics.









Diving into the oceans for new cures

While it has become increasingly common to develop synthetic drugs to treat diseases, we should remember that the world around us is full of hidden silver bullets that can help. Some of these treasures have been long known, for example red seaweeds, which have been prevalent in the diets of Asian communities for thousands of years.

Although several studies have shown that Asians who eat seaweed regularly have lower risk of colon, colorectal, and breast cancer, it was unclear which component was responsible for the anti-cancer effects. In a new study researchers have shown how these algae confer health benefits.

To understand what molecules are responsible, the team broke down the structure of different types of red seaweed and tested the sugars that were produced to see which one of them caused health benefits. Interestingly, they found that the sugar agarotriose worked as a prebiotic—it improved the growth of probiotic bacteria. "These results show us that when we eat red seaweed, it gets broken down in the gut and releases these sugars which serve as food for the probiotic bacteria. It could help explain why Japanese populations are healthier compared to others," said Eun Ju Yun, a former postdoctoral researcher at the IGB.

Another sugar, 3,6-anhydro-L-galactose or AHG, also showed promise, but in a different context. The researchers found that it inhibited the growth of human colon cancer cells by triggering cell death, leaving normal cells unharmed. Collectively, these results show that we may not have to look too far to find new cures; some of them can be found in ancient practices. Maybe we still have a lesson or two to learn from the past.

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Neal Andruska, **Matthew Boudreau, Karen Chen,** Marley Dewey, **Darjan Duraki, Alicia Arredondo Eve, Timothy Fan, Brendan Harley (Theme Leader),** Madeline Henn, **Paul Hergenrother (Theme leader), Yong-Su Jin, Benita Katzenellenbogen,** John Katzenellenbogen, Ji Eun Kim, Kyoung Heon Kim, Sung Hoon Kim, **Vasiliki Kolliopoulos, Jing-Jing Liu, Yu-Jeh Liu, Zeynep Madak-Erdogan,** Chengjian Mao, **Erik Nelson, Mai Ngo,** Edward Roy, David Shapiro, Bingtao Tang, Lawrence Wang, Sora Yu, Eun Ju Yun, **Quianying Zuo**

ACPP, BSD, CABBI, CGD, EIRH, GSP, MME, MMG, RBTE

Marine Drugs, Materialia, nutrients, Science Translational Medicine

Korea Institute of Planning and Evaluation for Technology in Food, Agriculture, Forestry, and Fisheries; Korean Federation of Science and Technology Societies; Ministry of Oceans and Fisheries, Korea; NIH; National Research Foundation of Korea; NIH; NSF; Systems Oncology; University of Illinois; U.S. Department of Defense

左倩颖
Qianying Zuo

PEOPLE BEHIND THE SCIENCE

Qianying Zuo's childhood had what every kid dreams of—unfettered access to movies. Her grandfather worked in a movie theater, which allowed her to watch whatever she liked. Perhaps this experience, above all else, fostered her hunger to see the world.

Zuo grew up in Nantong, a small town on the northern bank of the Yangtze River. Her time was split between her parents and her maternal grandparents. Zuo is especially attached to her grandfather, who has always been a source of inspiration. "He was a teacher for 10 years in a small town. He later changed his job so that he could move all of us to a bigger town and save my grandmom from doing farm work," Zuo said. "I grew up playing in the movie theater and I always got free tickets."

Zuo with her grandfather

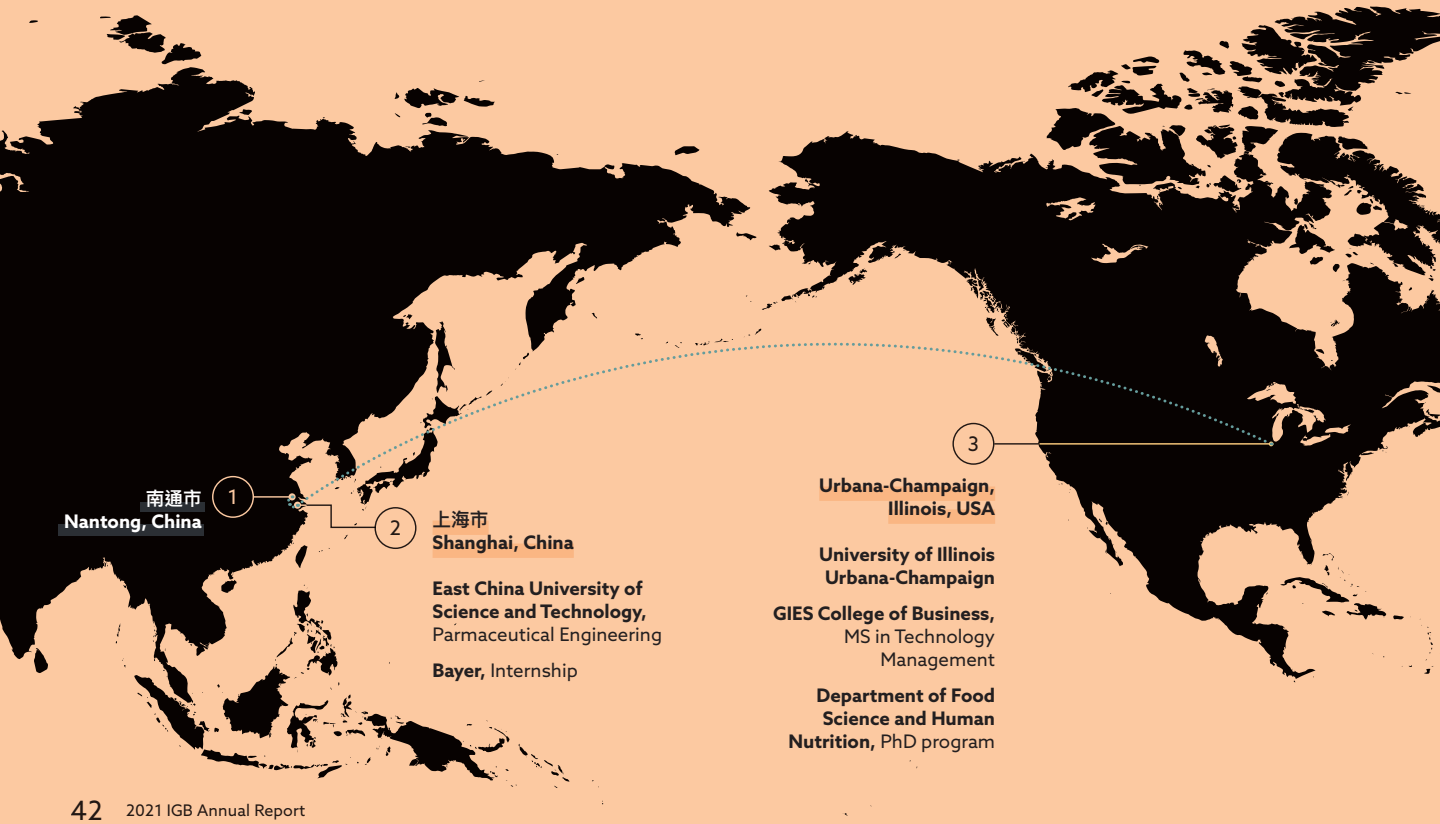
Growing up Zuo wanted to be a teacher or a doctor like many children. When it was time to choose her college major, she selected pharmaceutical engineering in the East China University of Science and Technology. "My parents were supportive and told me I could study whatever I wanted. Although my mom wanted me to be a teacher, I wanted to explore as many opportunities as possible before settling," Zuo said.

During her undergraduate studies, Zuo became fascinated with chemistry. "It was one of my favorite subjects. If you change one part of a molecule, you can change its entire property. I always did very well in my classes and that gave me a lot of confidence," Zuo mentioned with a smile.

After graduating in 2016, Zuo wanted to try her hand at business. She interned at Bayer in Shanghai. "I always want to try new things to see what I like," Zuo said. "Since it was a life science company, it was related to my major and it gave me a taste of what industry jobs are like."

After her internship, she decided to do a one-year business program at the University of Illinois. "Since I wasn't sure I wanted to commit to a six-year PhD program, I chose to do the business program instead. It welcomed everyone, irrespective of their background and experience. It was fun to learn from my classmates," Zuo added.

Why did she choose Urbana-Champaign of all places? "I wasn't very good at geography and so I didn't know that Illinois was in the middle of the US. I chose it because I liked the name 'Champaign'. Once I got here it was…different," Zuo giggled. She had spent so much time in a bustling metropolis like Shanghai that she was taken aback by the unending corn fields. She has since adjusted. "The longer you stay, the more you love this place. The people are nice and the work-life balance is good," Zuo said.



“做你自己，把握细节/机会，成为自己命运的主人。”

“Be yourself, grasp all the opportunities in your life, and become the master of your own destiny.”

QIANYING ZUO

GRADUATE STUDENT

DEPARTMENT OF FOOD SCIENCE AND HUMAN NUTRITION

She also had to adjust to the classroom culture in the US. “In China we listen to the teachers and absorb what they have to say. On the other hand, in the business program we had to work in a team,” Zuo said. “Since my English wasn’t very good, I was shy and afraid of making mistakes. It was really challenging to give my opinions. After years of training, I now feel more confident.”

After finishing her program, Zuo joined the PhD program in the Department of Food Science and Human Nutrition. She works on breast cancer research with Zeynep Madak-Erdogan, an associate professor of nutrition. “It was a great fit because she does a lot of data analysis, machine learning, RNA sequencing, and wet lab experiments,” Zuo said. Her two projects include using pathway preferential estrogens to target non-alcoholic fatty liver disease in postmenopausal women and improving the current drugs that are using to treat liver metastases using dietary interventions.

One of the biggest challenges she faced was dealing with animal studies. “We were using different doses of pathway preferential estrogens and we had to remove the ovaries from the mice. I was a little afraid initially because I didn’t know how to hold on to them,” Zuo said. “My advisor taught me how to perform the surgeries and I grew more confident with each one. Now I can’t remember how many I have done.”

Her lab also helps Zuo feel at home. “We have a very nice lab environment; my lab mates are like my siblings,” she said. “When I was interning at Merck, New Jersey last year one of my lab mates took care of my cat for six months. In addition to helping each other, we also do group lunches or dinners, celebrate birthdays, and have parties together.”

In her free time Zuo loves traveling. Before she came to Urbana-Champaign, she traveled across Europe with her best friends. According to her, even though they didn’t have a lot of money, the experience was wonderful. She also spends time volunteering to teach children Mandarin. “Before COVID-19 I spent two hours every Sunday afternoon teaching them and I also practiced my English,” Zuo said. She is now studying Korean in an attempt to follow her favorite Korean TV shows.

Zuo is open to a wide range of job opportunities after her PhD. “Although I still want to do work that is related to life science, I know there are many ways to do research. I prefer the industry because I want to be a business-minded scientist,” she said. “I am also open to postdoctoral training because I want more opportunities to learn about the different aspects of collaboration in science.”

Scientists discover how antibiotics penetrate Gram-negative bacterial cell walls

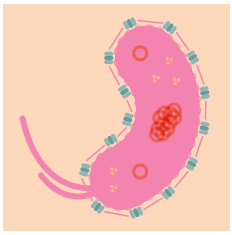
Researchers have developed a new method to determine how antibiotics with specific chemical properties thread their way through tiny pores in the otherwise impenetrable cell envelopes of Gram-negative bacteria.

"Antibiotic resistance is a major clinical problem," said biochemistry professor Emad Tajkhorshid, who led the study with Ph.D. students Nandan Haloi and Archit Kumar Vasan, and research scientist Po-Chao Wen. "Tens of thousands of people die each year in the U.S. as a result of untreatable bacterial infections, and the problem is worse in other parts of the world."

Some antibiotics can use specific membrane pores to penetrate the cell membranes of Gram-negative bacteria only if chemists add a positively charged group. While experiments proved the idea worked, the researchers did not understand why it did.

To gain a better understanding, they had to determine how the antibiotic interacted with different parts of the bacterial pore by using supercomputers to model the chemical characteristics of the system and running simulations that revealed how it behaved. To reduce the computational load, Haloi and Vasan developed a method that generated the most likely pathway for the antibiotic as it wriggled through the pore.

This effort revealed that the positively charged groups on the antibiotic interacted with negative charges lining the bacterial pore, allowing the antibiotic to line up in an energetically favorable manner as it moved through the narrowest part of the pore. The resulting technique will be useful for other explorations of molecular biology.



go.igb.illinois.edu/GNwall

Emily Geddes
Nandan Haloi
Paul Hergenrother (Theme Leader)
William Metcalf (Theme Leader)
Arjun Prasanna
Emad Tajkhorshid
Archit Kumar Vasan
Po-Chao Wen

IGB

ACPP
MMG

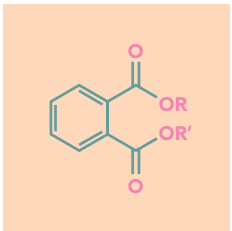
Chemical Science

NIH
NSF

Prenatal exposure to phthalates damages reproductive tissue in female mice

Phthalates are a ubiquitous family of chemicals that are used every day. In a new study, researchers have investigated how these compounds affect tissue development in the reproductive systems of female mice offspring.

"Phthalates are found everywhere: building products, personal care products, food and beverage containers, and medical equipment," said Jodi Flaws, a professor of comparative biosciences.



go.igb.illinois.edu/RTphthalate

Emily Brehm
Kathleen DeLeon
Jodi Flaws (Co-theme Leader)
Sarah Gill
Justin Ka-Hong
Daryl Meling

IGB
EIRH
MME

Reproductive Toxicology

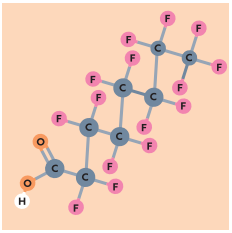
Billie A. Field Fellowship
NIH

Previous studies by the group have found that phthalate mixtures disrupt female reproduction, change organ weights, and cause ovarian cysts. In the current study, they are looking at how these mixtures affect ovarian steroidogenesis—a process that produces hormones that are required for reproduction—in female mice offspring. The researchers also looked at folliculogenesis, which is essential for fertility.

In the study, the pregnant mice were orally given either a control or a phthalate mixture every day from the first day of pregnancy till birth. The ovaries of the female offspring were then collected 60 days after birth and the tissues and their hormone levels were analyzed.

The female mice whose mothers had been exposed to phthalates had lower levels of estrogen, testosterone, and progesterone compared to the controls. The results indicate if mothers are exposed to phthalates during their pregnancy, it can interfere with the female offspring's ability to make normal levels of hormones.

The researchers are now investigating whether male offspring are similarly affected and to see whether phthalate exposure affects other female reproductive organs. They will also investigate whether these changes get passed on to subsequent generations.



go.igb.illinois.edu/PFASgrowth

Ozan Berk Imir
Joseph Irudayaraj
Alanna Zoe Kaminsky
Yu-Jeh Liu
Zeynep Madak-Erdogan
Ratnakar Singh
Michael J. Spinella
Qianying Zuo

IGB
CGD
EIRH
GSP
ACPP
MME

PFAS exposure, high-fat diet drive prostate cells' metabolism into pro-cancer state

Exposure to perfluoroalkyl and polyfluoroalkyl substances (PFAS)—a class of synthetic chemicals utilized in food wrappers and nonstick cookware—reprograms the metabolism of benign and malignant human prostate cells enabling them to proliferate at three times the rate of non-exposed cells.

"Our data suggest that exposure to PFAS synergizes with dietary fat to activate the protein-coding gene PPARa, escalating the carcinogenic risk in normal prostate cells while driving tumor progression in malignant cells," said food science and human nutrition professor Zeynep Madak-Erdogan.

The scientists found that PPARa was expressed at greater levels in the tumor cells of PFAS-exposed mice that ate the high-fat diet. The study's findings are believed to be the first to shed light on the synergistic interactions of PFAS and dietary fat and the metabolic changes that shift benign prostate cells to a malignant state.

The scientists injected an aggressive form of malignant human prostate cells into the flanks of male mice that were fed

either a high-fat diet intended to mimic the typical Western diet or a control diet. Some of the mice also received oral doses of perfluorooctane sulfonate (PFOS), a common form of PFAS that has been associated with various cancers. After 40 days the fastest tumor growth occurred in the group of mice that ate the high-fat diet and received PFOS exposure.

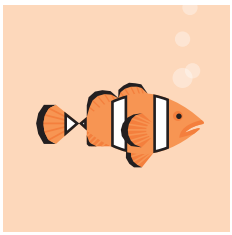
According to co-author Joseph Irudayaraj, a Founder Professor of Bioengineering, exposure to PFOS significantly upregulated genes associated with metabolism, particularly acetyl-coenzyme A which facilitates the metabolism of fatty acids and steroids.

nutrients

University of Illinois
USDA

Chemical pollutants disrupt reproduction in anemonefish, study finds

Ocean pollution is unfortunately becoming more commonplace, raising concerns over the effect of chemicals that are leaching into the water, such as the endocrine disrupting chemicals bisphenol A (BPA) and 17-ethinylestradiol (EE2). Researchers have now discovered how these chemicals can affect the reproduction in common anemonefish *Amphiprion ocellaris*.



go.igb.illinois.edu/BPAfish

A. ocellaris live in small groups with one alpha female, one beta male, and lower ranking non-reproductive males. Their sex is not genetically programmed and, instead, is dependent on environmental cues: A male transforms into a female if the female is removed from the group or if males are paired together.

Supriya Bhuvanagiri
Sarah Craig
Jose Gonzalez
Abigail Histed
Achint Kaur
Dominica Lange
Ewelina Nowak
Coltan Parker
Justin Rhodes

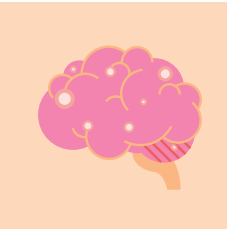
The researchers paired sexually immature male fish and fed them twice daily with normal food, food containing BPA, or food containing EE2. The researchers found that fish that were fed BPA had no testicular tissue; lower androgen levels, just like female fish; and increased expression of genes in the brain that are responsible for feminization. Surprisingly, although females tend to be more aggressive, BPA decreased aggression in these fish. In contrast, the effects of EE2 were similar, but less pronounced.

GNDP

Hormones and Behavior

NIH

It is still unclear how BPA is exerting its effects. In other studies BPA was thought to bind to estrogen receptors. However, since EE2 is an estrogen mimic and has subtle effects, the researchers believe that BPA has other additional effects. It is clear, however, that BPA can influence the population numbers since once the fish turn into females in the wild, they can't go back to being a male.



go.igb.illinois.edu/Epistudy

Eric Bolton
Hee Jung Chung
Catherine Christian-Hinman
Eung Chang Kim
Justin Rhodes
Andy Tang
Jiaren Zhang

GNDP
M-CELS

Proceedings of the National Academy of Sciences

NIH

Gene mutation leads to epileptic encephalopathy symptoms, neuron death in mice

Patients with epileptic encephalopathy begin having seizures when they are born, and display progressive developmental delay, intellectual disability, and autism-like behavior, according to Hee Jung Chung, a professor of molecular and integrative physiology.

Previous work from Chung's group found that epileptic encephalopathy is correlated with a mutation in a gene that codes for a potassium channel essential to regulating neuron activity. Yet, whether and how the mutation played a role in epileptic encephalopathy remained unknown.

Chung's group, in collaboration with psychology professor Justin Rhodes and molecular and integrative physiology professors Eric Bolton and Catherine Christian-Hinman, bred a population of mice with the gene mutation. The researchers studied the mice from birth to observe whether they developed symptoms and how the mutation affected their brains and the expression of the potassium channels.

The mice developed spontaneous seizures analogous to human patients, who begin having seizures as infants. The mice also had an increase in mortality—half of mice with the mutation died as juveniles. The surviving mice showed significant deficits in learning and memory, as well as repetitive behaviors associated with human autistic behavior.

The findings open up two potential therapeutic targets: the defective potassium channel and the inflammation and neural degeneration. The researchers want to study what causes the neurons to die and whether other mutations to the potassium channel cause the same symptoms. They also hope to use the mutant mouse line to study potential treatments.

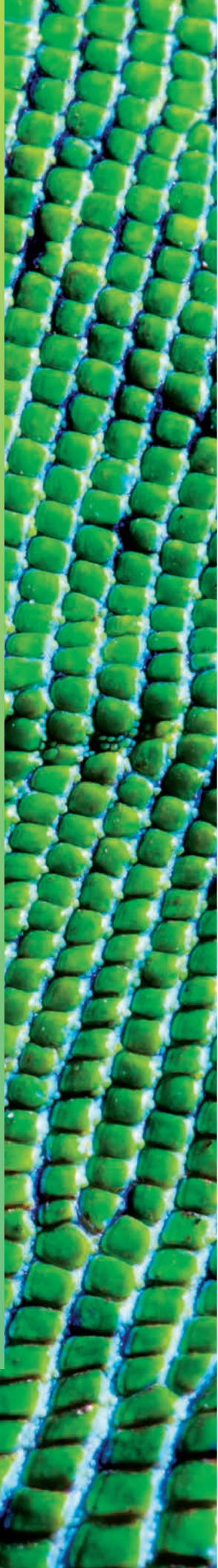
Stress and the animal kingdom

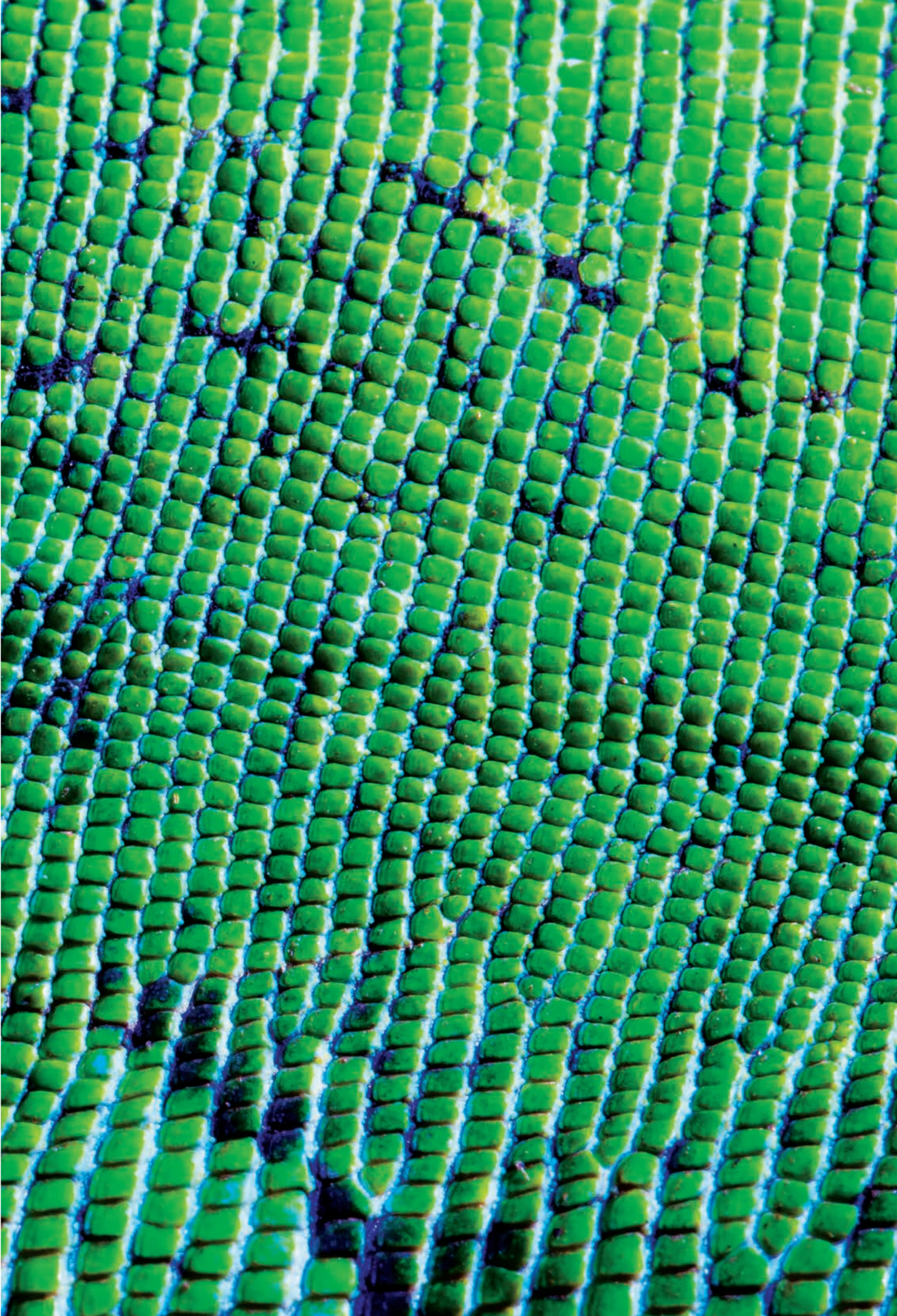
Have you ever been in a situation where your palms are sweaty, your knees are weak, and your arms are heavy? It's possible you were gearing up for public speaking, running away from a threat, or any number of other situations where you felt a loss of control. →

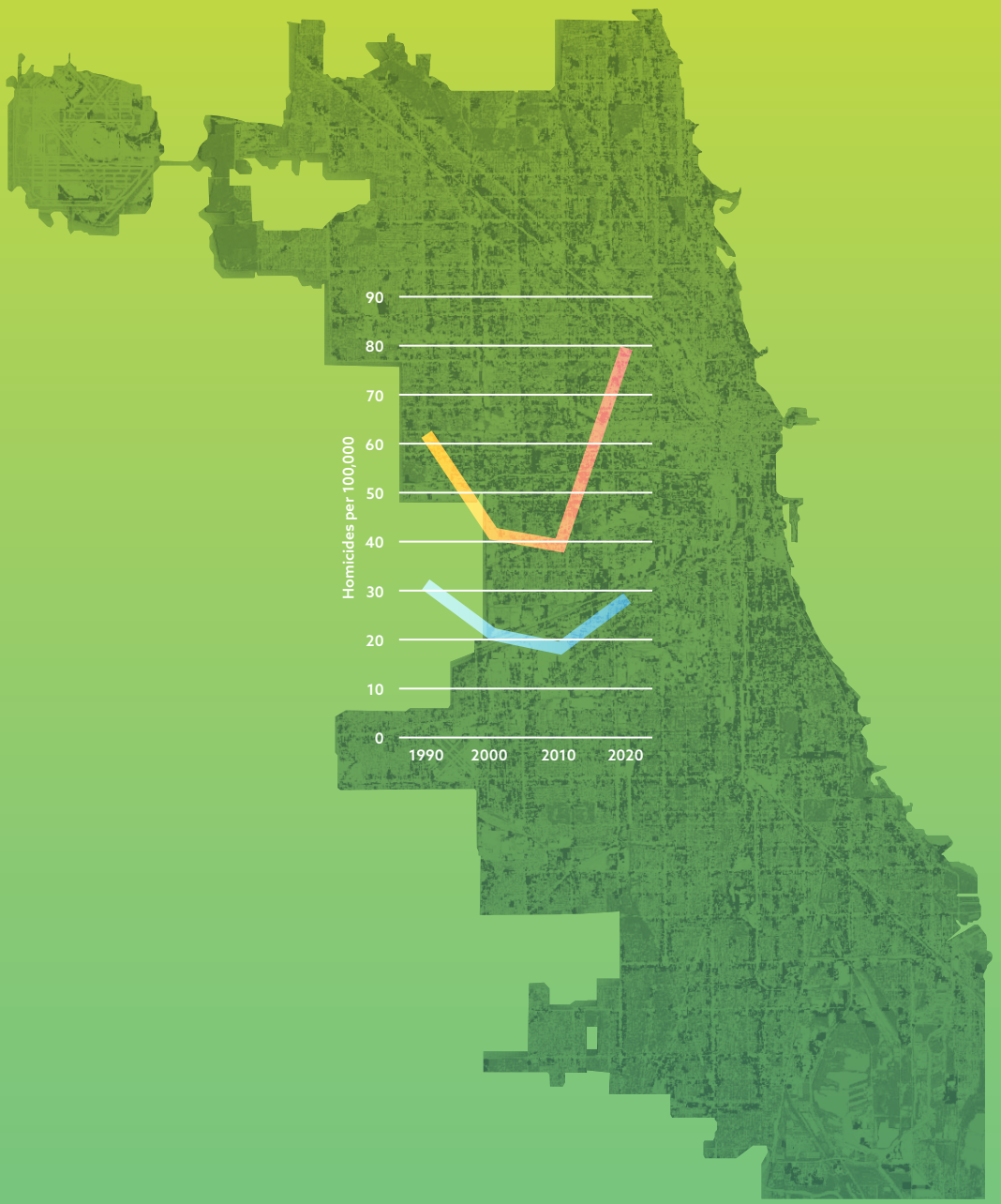
Violence alters gene expression

Why pregnant pigs need to be kept healthy

How threespine sticklebacks teach their offspring about stress







Average homicides per 100,000

Average homicides per 100,000 in Black communities

Your body is hard-wired to protect you against stress from aggressors. It does so by releasing fight-or-flight hormones or activating the immune system so that you can respond quickly to dangerous situations. Sometimes this response is useful—we deliver rousing speeches or run marathons. Once the event is over, our body resets over and there are no lasting effects. Other times, the repercussions are dangerous.

Violence alters gene expression

A new study of low-income single Black mothers on the South Side of Chicago showed that the chronic stress of living in neighborhoods with high rates of violence and poverty alters gene activity in immune cells. These changes reflect the body's "hunker down" response to long-term threats, a physiological strategy for lying low and considering new actions rather than launching an immediate fight-or-flight response.

Pictured, from left: Sandra Rodriguez-Zas, animal sciences; Andrew Greenlee, urban and regional planning; Gene Robinson, entomology and Ruby Mendenhall, sociology and African American studies.

The researchers surveyed 68 women from high-violence neighborhoods who shared their stories, filled out stress assessments, and gave blood samples. By referring to these surveys and police records of violent crime, the researchers measured levels of stress related to racism, poverty, and neighborhood violence. Then, they studied how genes related to stress and immunity differed between participants who perceived their neighborhoods as dangerous and those who did not.

Although the researchers saw no significant differences in genes associated with a flight-or-flight stress pathway, they found that women who reported greater neighborhood danger showed greater activity of genes regulated by the glucocorticoid receptor—a stress-response pathway that previously has been documented in animals' hunker-down response to persistent, overwhelming threat. The response helps the body bide its time and preserve itself for better days in the future. Unfortunately, if the situation does not improve, the hunkered-down body may not do the ongoing maintenance work needed for optimal health.

"Increased glucocorticoid activity is typically associated with aging, so it's as if these women are showing signs of accelerated aging, which is thought to be one reason that stress can lead to worse health outcomes," said Clare Rittschof, an assistant professor at the University of Kentucky and a former postdoctoral researcher in Gene Robinson's group.

The findings of the study are consistent with medical schools around the country declaring racism as a health crisis. It is imperative that health care and social services providers are trained to improve health outcomes that are caused by stress. According to the researchers, these efforts must be coupled with policies broadly aimed to eliminate structural racism in our society, a big source of stress for communities of color and other marginalized populations.

Why pregnant pigs need to be kept healthy

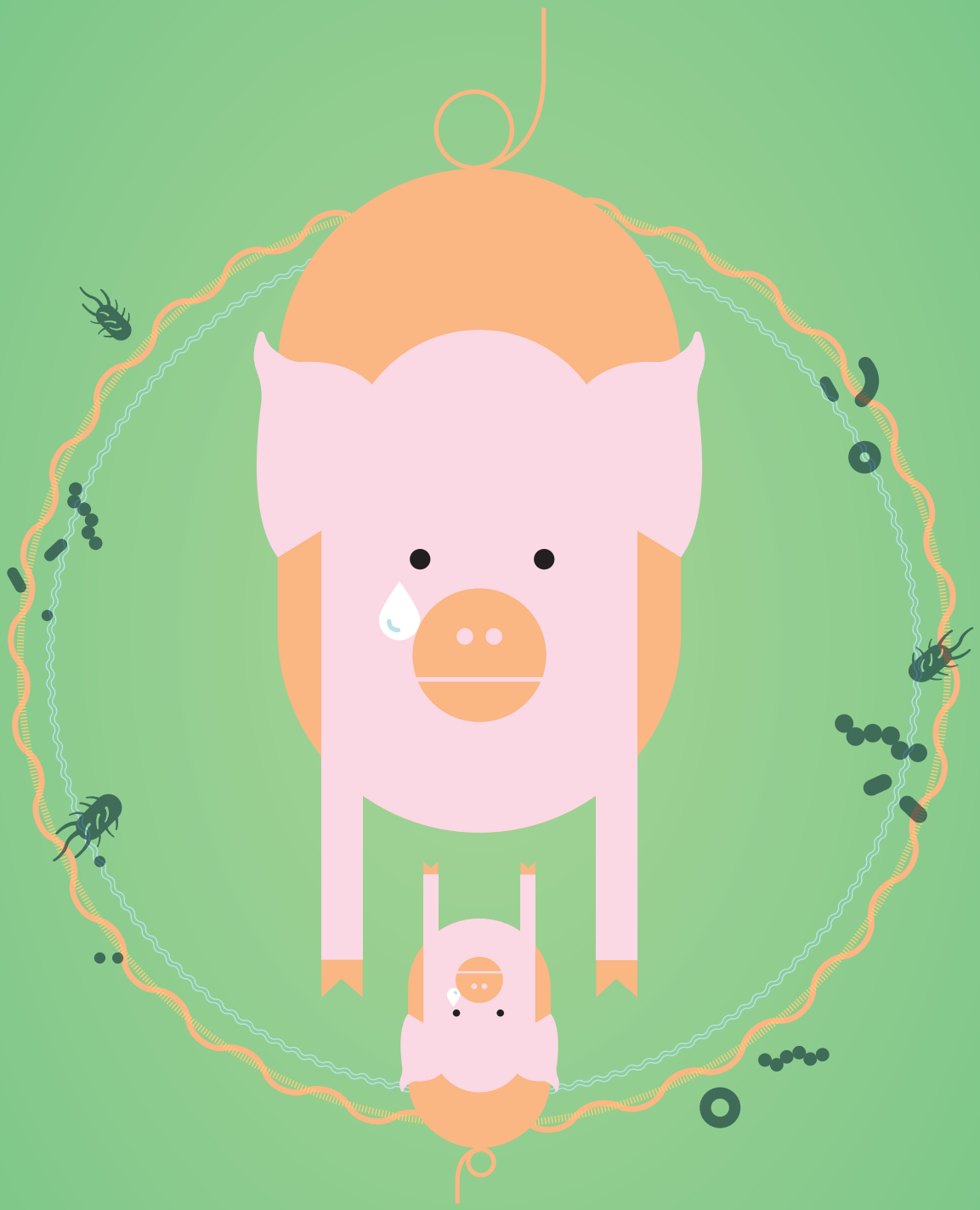
From left: Sandra Rodriguez-Zas, Laurie Rund, Courtni Bolt, Olivia Perez, Haley Rymut, and Marissa Keever-Keigher.

Although we usually encounter stress in the context of human lives, the response is omnipresent in the animal kingdom. Animals endure many stressors including diseases, predators, conflicts with neighbors, and fluctuations in food and water availability. Concerningly, some animals may never face stress, but instead inherit its negative effects from their parents.

New research shows that developing piglets, especially males, are negatively affected if their mothers suffer from illnesses during key stages of pregnancy. When such piglets experience a second stressor in early life, they are at a higher risk of neurological disorders.

The study was based on how the piglets behaved when they were challenged with weaning, a stressful time during a piglet's life where they have to deal with a broad array of stressors, including physical stressors from being handled and moved and emotional stressors from being taken away from the mom and placed with their peers. The researchers looked at a combination of factors: whether or not their moms were infected with porcine reproductive and respiratory syndrome virus during gestation, and whether or not they were weaned at 21 days of age, the typical age in production settings.

The results were conclusive. Pigs from virus-infected mothers often showed anti-social behaviors. Because they are typically group-housed and fed via communal feeders, pigs that don't like being around their peers are often last to feed and are generally more stressed, leading to slower growth rates. Additionally, many of the genes expressed in weaned piglets from virus-infected mothers were associated with autism spectrum disorder, schizophrenia spectrum disorder, and Huntington's and Alzheimer's disease. The study provides



valuable clues for researchers studying neurodegenerative disorders in humans, even though some aspects might not translate directly.

Alison Bell, a professor of evolution, ecology, and behavior.

How threespine sticklebacks teach their offspring about stress

While some parents may be the cause of their offspring's increased stress levels, other parents try to teach the next generation lessons in resiliency so that the descendants can thrive in their hostile environments. But how do they impart their wisdom? In the case of the threespine stickleback fathers, they send signals through their sperm and parental behavior.

Previous studies from the Bell lab showed that in the presence of predators, male sticklebacks alter their parental care and produce offspring that are more timid, potentially leading to higher survival against predators. However, it was unclear whether epigenetic changes—reversible modifications in genes that are caused due to the environment—in the sperm could influence the future generations.

The researchers used two groups of fathers: those that were exposed to a predator before they fertilized the eggs and those that were not. The offspring from the two groups were then raised with or without parental care. The offspring of predator-exposed fathers were less active and also seemed to be less stressed when they are exposed to a simulated predator attack. Interestingly, the effect was present whether or not their fathers provided care.

"The results are definitely not what we expected," said Alison Bell, a professor of evolution, ecology, and behavior. "It is clear that parental effects can depend on the population i.e., where the sticklebacks are from, when fathers experience risk, and what traits are being measured."

The researchers are currently studying two ecotypes—the same species differing in various respects, such as parental care—of sticklebacks. One ecotype provides parental care, like the regular stickleback, and the other does not. By doing so, the Bell group hopes to understand the genetic basis for this difference and how the offspring have evolved to the loss of care.

go.igb.illinois.edu/3dads
go.igb.illinois.edu/Hunker
go.igb.illinois.edu/Pigstress

Adrienne Antonson, **Alison Bell (Theme Leader)**, Courtni Bolt, Megan Caputo, Erika Carlson, Steve Cole, Andrew Greenlee, Alvaro Hernandez, Jennifer Hellmann, Alexandra Houser, Rodney Johnson, Marissa Keever-Keigher, Meggan Lee, **Ruby Mendenhall,** Clare Rittschof, **Gene Robinson, Sandra Rodriguez-Zas,** Laurie Rund, Haley Rymut, Bruce Southey, Pan Zhang

GNDP

Animal Behaviour, G3 Genes|Genomes|Genetics, Psychoneuroendocrinology

American Genetic Association, NIH, University of Illinois, USC/UCLA Center on Biodemography and Population Health, USDA

سبا غفاری
Saba Ghaffari

PEOPLE BEHIND THE SCIENCE

For as long as Saba Ghaffari can remember, she spent her life in the pursuit of knowledge. During the first 10 years of her childhood, she grew up in Torbat-e Heydariyeh, a small town close to the eastern border of Iran. She spent her days playing with her pets: roosters, hens, and ducks. Her family later moved to Tehran to give her better educational opportunities.

"Most of my family members are doctors and university professors. It's a part of our culture to study science. Growing up, my only job was to study while my parents took care of everything including the finances and the household chores," Ghaffari said. "If I was born anywhere else, I would have chosen to be a fashion designer as it is my other passion besides studying science," she added with a laugh.

In addition to her academic pursuits, Ghaffari sought out new subjects to study. During the summers she would enroll in classes that weren't taught in school. "I went to advanced physics and astronomy classes, read scientific books, and watched documentaries on many different topics. My schoolmates were amazed that I found comfort and entertainment in doing so," she said. "I also had this passion of taking notes on everything I heard and I thought about. I wrote down my ideas on how to solve existing problems in ways that people have not approached them."

first because she was passionate about many research fields. "I had experience in computer vision, computational biology, and several other fields. In the end I chose computational biology because it was an interdisciplinary field full of exciting challenges and opportunities," Ghaffari said.

After joining the University of Illinois in August 2017, Ghaffari worked with Saurabh Sinha to develop computational models on colon cancer metastasis and dihydropyrimidine dehydrogenase deficiency, a condition that can cause neurological problems in infants. "I like how my projects keep me engaged. I like thinking the problems through and solving them methodically," she said. "I'm hoping that as the field of computational biology grows, I will be able to work on projects that will lead to meaningful discoveries."

Although Ghaffari is now comfortable with her workload in graduate school, her first few years

For her undergraduate studies, Ghaffari joined the Sharif University of Technology, where she majored in electrical engineering and minored in computer science. "During my undergraduate years, I was lucky to get an internship at the Chinese University of Hong Kong. After that experience, I was determined to study in universities outside Iran for my PhD," she said.

When she needed to choose what she wanted to study for her PhD, Ghaffari was confused at

were rocky. "I had to learn how to do everything by myself. It was like being born again because I had to rebuild the life I used to have back in my hometown. For some time, I lost track of what my PhD was about," Ghaffari said. "Right now, however, I can accomplish a lot more in the time I have left."

Ghaffari is keeping an open mind about what she wants to do after she completes her PhD program. "Although I think that there is a lot

ضرب المثل:
”درخت هر چه پر بارتر افتاده تر“

Quote:
"The more fertile the tree, the lower it stays to the ground."
The saying implies that the more you learn, the humbler you become.

SABA GHAFFARI
GRADUATE STUDENT
DEPARTMENT OF COMPUTER SCIENCE

These are a few of Saba's favorite things

of competition in academia and you have to worry about funding, I like that you can work on different projects. If you are a good thinker and you have good ideas, you should remain in academia. In the industry you don't have to be worried about funding, but you have to work to fulfil the company's purposes," Ghaffari said. "I will apply to both academia and the industry and see what happens."

In her spare time Ghaffari loves traveling and painting. "I try to go to Colorado to ski once a year. I miss the mountains and the sea because Tehran has a lot of mountains and it's four hours away from the Caspian Sea. I also really like the colorful trees here. When you live in a big city, you have to go to a park to see them, but here they pop up everywhere," she said. "I paint and draw, but I miss all my artwork that I left behind in Iran. I also miss my parents. I came here when Trump declared a travel ban and my parents could not come here. I have a single-entry visa and I haven't gone home in five years."

Comparing the pathogen numbers in backyard and commercial composts

Compost—organic material that is added to soil to help plants grow—is widely used by gardeners because it improves soil health and reduces the amount of organic waste in landfills. Although several studies have looked at commercial composts, very few have investigated backyard compost samples. In a new study researchers have measured the number of pathogens in both types of compost.

The main difference between the two types is the composition. Backyard compost is made from plant-based materials whereas many of the commercial composts are made from farm manure, according to Yuqing Mao, a graduate student in the Nguyen lab. Regardless of the source, the process of composting usually gets rid of pathogens because it involves multiple stages of high heat.

The researchers collected samples of backyard compost from two gardeners at Urbana-Champaign and used six types of commercial compost, which were bought from the supermarket. They also used two controls: soil that has never been treated with compost and immature compost. They extracted DNA samples and used qPCR to identify and measure the abundance of specific genes. The group found that *Legionella pneumophila* was present in four of the commercial samples, and *Mycobacterium spp.* and *Pseudomonas aeruginosa* were found in both backyard and commercial compost samples.

It is unclear how the airborne pathogens are finding their way into the compost samples. The researchers are now trying to understand the source of contamination better so that they can help protect gardeners.

go.igb.illinois.edu/CompostPath

Neslihan Akdeniz
Yuqing Mao
Helen Nguyen

IGOH

Science of the Total Environment

EPA
National Institute of Food and Agriculture
University of Illinois
USDA

New computational models to understand colon cancer

Although the development of secondary cancerous growths, called metastasis, is the primary cause of death in most cancers, the cellular changes that drive it are poorly understood. In a new study, researchers have developed a new modeling approach to better understand how tumors become aggressive.

The researchers pooled the data from their own experiments as well as publicly available data to develop the model, which was based on a simpler 2018 model that investigated regulators of cancer drug resistance. In this paper, they specifically focused on transcription factors, which are proteins that control gene expression by binding to the DNA. The model

go.igb.illinois.edu/CCmodel

Saba Ghaffari
Saurabh Sinha

IGB
BSD
CABBI
GNDP
GSP

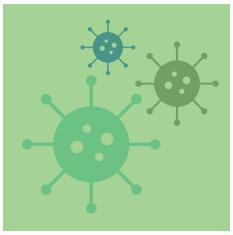
Genome Biology

NIH
University of Illinois
Mayo Clinic Center for Biomedical Discovery

allowed them to see whether the target areas that the factors bind to are available or not. The model was so adaptable that it was able to analyze the binding of transcription factors in other types of cells as well.

The researchers also tested the predictions of the model using human cancer cell lines. They looked at the transcription factors that were identified and showed that they were involved in increasing the aggressiveness of the colorectal cancer cells. Without the model, the process would have been expensive and time consuming.

"Increasingly, these technologies provide us complementary views of cellular changes during disease progression. This is just the beginning. We are looking at it as a blueprint for many more analyses in the future, tackling different biological challenges," said Saurabh Sinha, a professor of computer science.



go.igb.illinois.edu/CV19mutate

Gustavo Caetano-Anollés

IGB
GEGC

What happens when the coronavirus mutates?

New mutations to the COVID-19 virus are emerging, even as vaccines containing bits of viral genetic material are being distributed. Gustavo Caetano-Anollés, a professor of crop sciences, has been cataloging these genetic mutations. In an interview with News Bureau biomedical sciences editor Liz Ahlberg Touchstone, Caetano-Anollés discussed viral mutations and what it could mean for vaccinations.

RNA viruses, such as coronaviruses, have incredibly dynamic genomes. Not all mutations are relevant or are present in all proteins. However, some provide features that are beneficial to the virus, which it likes to preserve. Those features are fixed in the virus population because they are advantageous —for example, they allow the virus to spread more effectively. That often results in a strain becoming popularly sampled in genomic analyses, for example the B.1.1.7 variant isolated in the U.K.

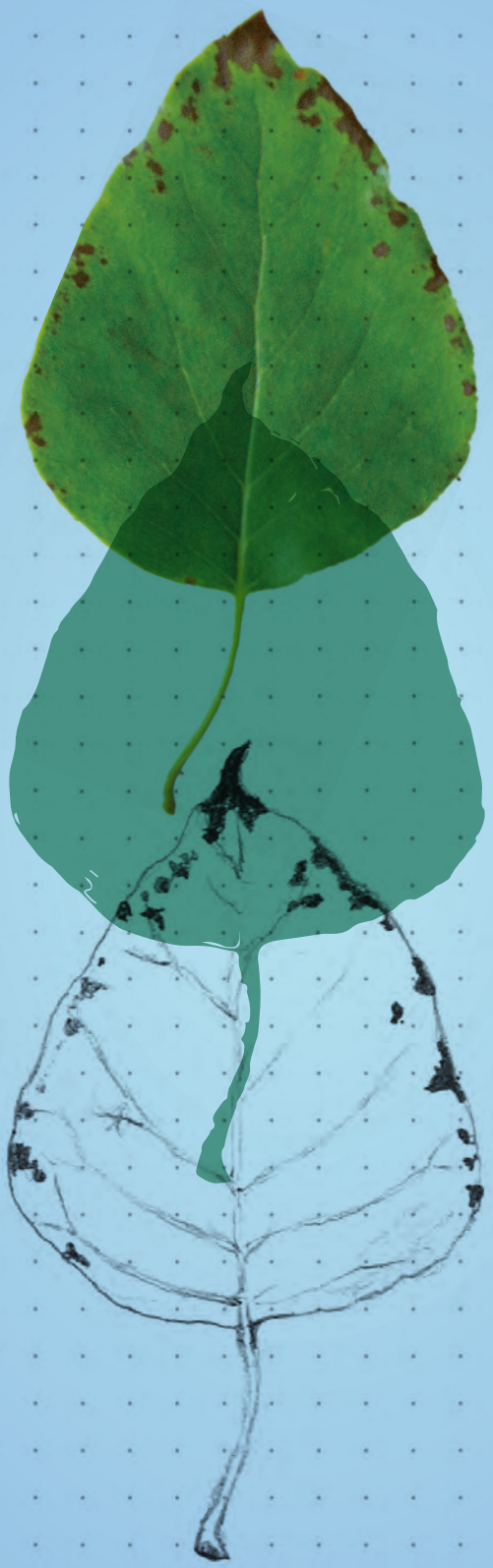
Although mutations occur at random, there are proteins that protect the virus-replication system from acting too wildly because many mutations could be deleterious. They would destroy its chances of finding more useful mutations. Yet too few mutations could eliminate opportunities for the virus to innovate. Fortunately, it appears that mutations such as those in the B.1.1.7 variant are not hitting sites with high antibody accessibility scores, which is good news for vaccination. The bad news is that those mutations interfere with virus detection in the PCR analyses used by most COVID-19 tests. This implies a lot of work to fix the problem of accurate testing.

How scientists can help drive societal changes

Scientific discoveries and innovations have played a pivotal role in all of our lives. Although the narrative often focuses on singular "geniuses", most scientific endeavors are achieved through the hard work of teams. The members of such research groups are often thought to be selected based on meritocracy—the idea that one rises solely based on their ability. Unfortunately, that usually translates into departments and labs sorely lacking in diversity, both in terms of gender and race. →

Nurturing budding scientists

Building bridges connecting Fisk to the University of Illinois



Why should we care? Complex problems require different perspectives. "Being smart" is often less important than looking at the problem from different angles. Diversity also balances biases that may arise from individual beliefs and backgrounds. By excluding certain groups of people, we lose many talented scientists and our collective future becomes dimmer as the next generation fails to find themselves reflected in today's researchers.

Aware of this problem, the IGB Committee on Diversity was established in 2018. Since then, it has been dedicated to creating a more diverse, inclusive, and welcoming environment within our community. The committee includes theme leaders, faculty, staff, and postdoctoral researchers, representing unique perspectives. Additionally, in 2021 the COD Task Force was formed to gather more individuals to accelerate initiatives that are meant to increase dialogue and create change internally. The Task Force has organized several events including talks and workshops that center around diversity, equity, and inclusion. They have also supported programs that increase participation from members in minority groups including Pollen Power, which introduces middle school girls to the world of biology research, and SING, the Summer Internship for INdigenous People in Genomics, which brings together Indigenous scientists and community members every year.

Nurturing budding scientists

Children are naturally inquisitive, questioning how the world works. If scientists take advantage of this innate curiosity, they can help children understand the process of scientific discovery, creating a new generation of enthusiastic researchers. This idea has led to the Pollen Power camp, which takes place over the summer and trains 6th to 8th grade students from underrepresented populations in STEM. The campers are encouraged to observe their surroundings as they learn about different aspects of plant biology.

Pollen Power camp activities revolved around observing nature with a scientific mindset.

Although the camp usually takes place in-person, in 2021 it was conducted virtually. "It was definitely interesting moving to a virtual camp," said Daniel Ryerson, an outreach activities coordinator at the IGB. "It was a challenge to design activities that the campers could do at home, on their own, that were still informative and engaging. Fortunately, it turned out better than

Chlorophyll extraction activity.

I hoped—the campers had a blast sharing what they learned and they taught us counselors some things too."

"I learned a lot about the different parts of a flower," said Allison, one of the campers. "It was interesting to see all the different pieces when I took it apart and the different bugs that were in the flower." Other campers enjoyed the chlorophyll extraction activity and identifying different fruits in an online game. "I learned about fruits in the guess-the-fruit game. I learned that lychee nuts were real and that they look like walnuts but are tinier," said Evie, another camper.

The IGB outreach team also partnered with the Franklin STEAM Academy in Champaign to help 6th-8th grade students conduct research. The effort took place from September 2020 to May 2021, and the students teamed up with researchers from IGB and students from University Laboratory High School. The Uni High students were recruited to serve as a bridge, since students may feel more comfortable forming connections with mentors who are closer to them in age.

The STEAM (Science, Technology, Engineering, Arts, and Mathematics) TRAIN (Transdisciplinary Research Across Institutional Near-peers) project was organized by the IGB's Outreach Senior Activities Coordinator Daniel Urban, Franklin's Magnet Site Coordinator Zanne Newman, and Uni High's chemistry teacher David Bergandine. Their main objective was to inspire autonomous, curiosity-driven student research through interactions with near-peer mentors. They hoped that the Franklin students would discover their love for science by exploring difficult issues that they're passionate about.

Daniel Urban, Outreach Senior Activities Coordinator.

Just like the Pollen Power camp, all the STEAM TRAIN participants met on Zoom. Nevertheless, the topics that were researched by the students rivaled what is explored by cutting-edge laboratories across the world: rocket fuels, bird navigation in adverse weather, carbon capture, designing disposable packaging, tissue regeneration, and bioluminescence.

"Throughout the year, the persistence and creativity of the students continued to astound us. As much as we hope the program benefited them, these kids served as a source of inspiration for us as well," Urban said.

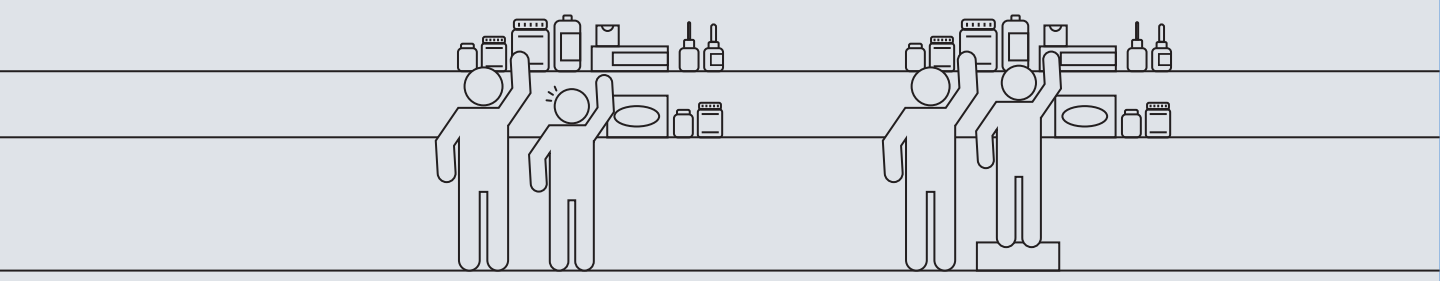
Building bridges connecting Fisk to the University of Illinois

When Founder Professor of Physics Jun Song speaks of the need for greater investment in the training of underrepresented groups in computational sciences, he often says that although education is considered as the great equalizer, it means nothing without equal opportunity. He has taken several steps to ad-

Fisk undergraduate student (from top) Leiana-Lavette Woodard, Jaia Holleman, and Skye Faucher.

dress inequality including establishing the FUTURE-MINDS-QB program in collaboration with Fisk University, a historically Black university in Nashville. The program offers rigorous training in core computational and mathematical skills required to succeed in big-data research fields. The participants get the chance to strengthen their doctoral program prerequisites and participate in a formal summer program of research and workshops at the University of Illinois while they are undergraduates at Fisk.

For Song, who has for many years worked on diversity-enhancing undergraduate-training programs in biological big-data science, the new program is the realization of a long-held goal to extend these efforts to the graduate level. He points out that this new effort and the prior Fisk-Illinois collaborative programs have been and will continue to be successful, only because they receive broad support from administrators, research centers, and faculty on both campuses. "As scientists and leaders in our respective fields, it's important that we ask ourselves what we can do to correct the longstanding inequality of access to computational sciences," Song said. "Our new program will produce a talented, insightful, and diverse pool of graduate students. Our job will be to make sure their experiences not only train them well on the fundamentals and applications of big-data science, but also to ensure their experiences are positive and that they are prepared and willing to enter the field and make their own contributions to biomedical and computational biology."



Equality
(Evenly distributed tools and assistance)

Equity
(Custom tools that identify and address inequality)

go.igb.illinois.edu/Pollen21
go.igb.illinois.edu/FMQB
go.igb.illinois.edu/STEAM21

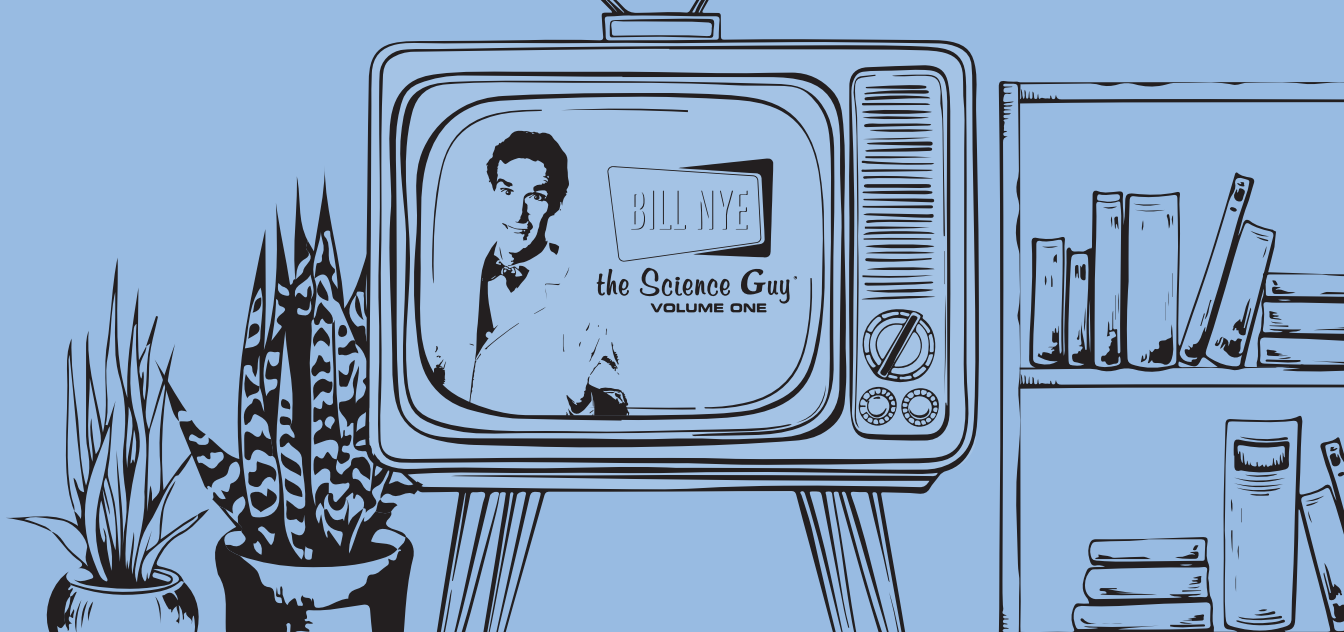
Lisa Ainsworth, Stephen Boppart, **Steven Burgess, Carla Cáceres, Adrienne Gulley, Katy Heath, Alisa King-Klemperer, Hyunjoon Kong (Theme Leader), Andrew Leakey (CABBI Director), Zeynep Madak-Erdogan, Ripan Malhi, Ruby Mendenhall, Gary Olsen, Daniel Ryerson, Jun Song, Daniel Urban**

ACPP, BCXT, CABBI, CGD, EIRH, GEGC, GNDP, GSP, IGOH, M-CELS, RBTE

Daniel Ryerson

PEOPLE BEHIND THE SCIENCE

What does a child who was obsessed with science fiction shows and Bill Nye the Science Guy grow up to become? One possibility is a passionate Outreach Activities Coordinator like Daniel Ryerson. "As a kid I always enjoyed science. I enjoyed the logical step-by-step process of analyzing a problem," Ryerson explained. "I would get obsessed with TV shows and not notice when people would walk in and talk to me. I enjoyed watching Bill Nye because he had a great way of visualizing a topic and making it interesting."



Ryerson grew up in Chicago. It was a running joke in his family that he would grow up to become a doctor or a researcher and cure his family history of diabetes. When he went to college at the University of Iowa in 2005, he started out as a pre-medical student. However, he enjoyed research more. "My thought process changed as I went through the college experience. I became more invested in classes about how things work and got less interested in treating patients," Ryerson said. In the end, he majored in general biology with a minor in chemistry.

Ryerson met his future wife Melissa in their freshman year. Living in the honors dorm, they connected over a shared a love of science. They took many classes together, formed study groups, and were lab partners. After graduating in 2009, Ryerson started looking for jobs that could support him during graduate school. When he learned of the scholarships and stipends available to graduate students, it was a dream come true. He began applying to schools in the Midwest as he and Melissa wanted to stay close to their families.

"When I interviewed at the University of Illinois, the campus was beautiful and the experience I had was amazing. I was immediately sold on it," Ryerson said. "I also ended up joining the lab of the professor I interviewed with: Jongsook Kim Kemper. She works on metabolic disorders like obesity and diabetes, and it was a full circle with what I was told during my childhood. I could finally do research on animal models of diabetes." Ryerson's wife also joined the School of Molecular and Cellular Biology, where she completed her PhD in microbiology.

Towards the end of graduate school, Ryerson wanted to explore careers outside academia. "I was starting to get burnt out on bench work and I wanted to look at what other jobs were out there. I had two friends who went into science outreach and I had never heard of it before," Ryerson said. "During graduate school I really enjoyed interacting with students, but grading and writing exams was less rewarding. Science outreach seemed like a great opportunity to focus on that student interaction."

Relatively stoic so far, Ryerson lights up when he talks about the outreach efforts he organizes at the IGB. "My favorite part is when you watch someone understand a science topic for the first time and you can see it click. It's the most rewarding part about science outreach," Ryerson said.

One of Ryerson's favorite outreach events is Pollen Power, a summer camp that is focused on middle school students. "They meet with scientists and go out into the field to collect pollen samples. They bring them in, look at them under the microscopes, and print 3D models. I highlight this camp whenever I talk about my job and the reaction I usually get from adults is 'Can I join too?'"

Ryerson also helps organize Genome Day, an open-house event for community members of all ages to learn about genomes, genes, DNA, and evolution. Before 2020, the event was held at the Orpheum Children's Science Museum and Franklin Middle School in Champaign. In 2021, the IGB outreach team partnered with Pygmalion, a multi-day festival that takes place every September in Urbana-Champaign.

Ryerson with his wife at Genome Day

“All you need to know is 1+1=2.”

My grandfather meant that when you have an insurmountable question, break it down to smaller pieces and work your way through.

DANIEL RYERSON

OUTREACH ACTIVITIES COORDINATOR

IGB OUTREACH

Members of the IGB Outreach and Communications team. *Inset: A miniature painted by Ryerson*

“Last year was our first outdoor Genome Day. The location had its own set of challenges, like the wind that blew around some of our activities. Also, the entrance was not in an ideal location but Melissa was able to stand in front and encourage everyone to come in. In the first hour we had only five people go through and I was terrified that no one was going to show up,” Ryerson said.

In the end, 442 people showed up, many of whom noticed the event as they were waiting for the CU Pride Fest. “Usually mostly kids show up and this was the first time so many adults came. We had 11 activity stations, but everyone was drawn to the tanks with frogs that Eva Fischer brought,” he said with a chuckle. “Even though it felt crazy and hectic leading up to it, the event was a lot of fun. We had 75 volunteers and I was very proud with how it turned out.”

“I absolutely love our outreach team,” Ryerson added. “Everyone comes together to make these amazing events and it’s probably one of my favorite things about the job. I am grateful for everyone on our team.”

In addition to organizing events that cater to kids, Ryerson also works with the Osher Lifelong Learning Institute at the University of Illinois, a nationwide program that is dedicated to working with adult learners. “OLLI is my favorite group to talk to; they are engaged and they always keep you on your toes by asking great questions. They come there with the goal of just learning, and that’s what I love,” he explained.

In their spare time, Ryerson and his wife are avid board game players. They also paint miniature figures and build miniature terrains for their games. Unsurprisingly, his hobbies also spill into his outreach events. “During Pollen Power we were supposed to talk about what interested us. Everyone brought cool science things and I brought my terrain building stuff,” Ryerson said. “I was super nervous, but the kids loved it. Being able to build things like that has helped me in thinking about what we can create for any outreach activity.”

Ryerson believes that the scale and number of events that the outreach team can conduct would be impossible without the support of the IGB. “I have not heard of other programs that dedicate the amount of funding, time, or personnel towards science outreach the way the IGB does,” Ryerson said. While he thought the outreach program at IGB was one of a kind he had a different perspective when asked about his audience. “Across all the different levels of activities and audiences we interact with, I am amazed at how much is the same. People have different types of questions but the sense of curiosity is always the same.”

Undergraduate students selected as 2021 Woese Research Scholars

The Carl R. Woese Undergraduate Research Scholar program is designed to inspire students to pursue important scientific questions. In 2021, Peyton Hopkins and Shreyaa Khanna were selected to carry out their research for a 10-week period, supported by a stipend from the IGB.

Peyton Hopkins is pursuing a degree in molecular and cellular biology and he has been working in the Reddi lab since 2020. Hopkins continued his research in the same lab where he studied the involvement of the protein TDP-43 in spermatogenesis in mice models. TDP-43 has been shown to have a role in several neurodegenerative disorders, including Alzheimer's disease and amyotrophic lateral sclerosis.

Hopkins is interested in applying to graduate school in the future. "I am trying to figure out my career trajectory as I go. However, I want to pursue biological research and I have become interested in studying male reproduction after working in the Reddi lab."

Shreyaa Khanna is also pursuing a degree in molecular and cellular biology, with a minor in bioinformatics. During the summer she worked in the Dar lab where she investigated the cell cycle in embryonic stem cells using a fluorescent indicator called FUCCI.

Khanna is currently a pre-medical student and she is interested in integrating clinical research with medicine. "One of the biggest lessons I have learnt is that research is the pursuit of something through trial and error, which is reflective of how life is—some things work and some things don't and you need to find what works best for you," Khanna said.

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Roy Dar
Peyton Hopkins
Shreyaa Khanna
Prabhakara Poothi Reddi

IGB

BCXT
GNDP
M-CELS

New study reveals the deep impact of research in LAS

Dozens of professors in the College of LAS, including many from the IGB, rank among the most-cited researchers in the world in a new, widely hailed analysis designed to provide a clearer view of scientific and scholarly impact. The datasets include about 8 million researchers worldwide—active, retired, or deceased—who published at least five papers in their career.

The study came in response to longstanding difficulties in interpreting citation impact among researchers. According to the authors, misinterpretations in citation impact stems

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John Cronan
Benita Katzenellenbogen
Jeffery Moore
Stephen Long
Yi Lu
Brent Roberts
Hugh Robertson
Gene Robinson
Carl Woese

BSD
CABBI
GEGC
GNDP
CGD
MMG

PLOS Biology

from several issues, including inaccurate self-reported data, unclear comparisons between fields, and inconsistent availability of research profiles. This study took measures to remove the impact of self-citation, for example, when researchers cite their own work. *Nature* magazine called the study the largest collection of self-citation metrics ever published.

According to the study, the most-cited LAS researcher since the mid-1990s is the late Carl Woese, professor of microbiology and IGB namesake who is best known for his discovery of archaea, a third domain of life. Ranked 650 on the list, Woese passed away in 2012.

Other LAS professors ranked in the top 10,000 on the list include Jeffery Moore, chemistry, 2,424; Stephen Long, plant biology, 2,851; Gene Robinson, entomology, 4,284; Benita Katzenellenbogen, molecular and integrative physiology and cell and developmental biology, 4,342; John Cronan, microbiology and biochemistry, 6,107; Yi Lu, chemistry, 6,384; Brent Roberts, psychology, 6,901; and Hugh Robertson, entomology, 9,041.

Graduate students awarded for their innovative proposals

The first Young Innovator Program concluded in August 2021; it was a ten-week summer program that was designed to teach trainees how to become innovative leaders in their fields. The program culminated in an idea competition, where the participants showcased the skills that they learned over the summer. The top three participants were awarded with tiered funds ranging from $5,000-$20,000.

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Funded by the Catherine and Don Kleinmuntz Center for Genomics in Business and Society, the program was developed by Cecilia Gentle, then IGB Economic Development Fellow, and Erin Louer, IGB's education coordinator and manager of the Kleinmuntz Center.

Alida de Flamingh
Kaiyu Guan
Brendan Harley
Paul Jensen
Vasiliki Kolliopoulos
Victoria Kriuchkovskaia
Walden Li
Ripan Malhi
Aleczandria Tiffany
Sheng Wang

The three winners were all graduate students in the lab of Brendan Harley, a Robert W. Schaefer Professor of Chemical and Biomolecular Engineering. Vasiliki Kolliopoulos, who won first place, plans to develop a novel platform to screen biomaterials for bone injuries. The second-place winner was Aleczandria Tiffany, who is developing an implant for tissue regeneration. Victoria Kriuchkovskaia won third place for her project which will attempt to develop a platform to screen drugs for glioblastoma.

CABBI
EIRH
GNDP
GSP
IGOH
MMG
RBTE

The other participants included Alida de Flamingh, a postdoctoral fellow in the Malhi lab, who is developing a genomic sex identification toolkit to help in animal conservation efforts; Walden Li, a graduate student in the Jensen lab, who is working on preventing cavities caused by *Streptococcus mutans* by using peptides; and Sheng Wang, a postdoctoral fellow in the Guan lab, who is combining satellite data and field data to monitor soil carbon levels and crop health.

New funds to support collaborative projects at the IGB

go.igb.illinois.edu/Elser21

IGB

EIRH

Denise Elser first learned about the IGB in 2017 and was intrigued by the social and ethical implications of advances in genomic sciences. During her subsequent visit in 2019, she was impressed by the different IGB themes and was inspired to help by making a generous contribution to the Director's Innovation Fund.

Elser grew up in Chicago knowing that she wanted to become a physician because she was fascinated by the inner workings of the human body. When she began looking at universities, Elser was won over by the program at Illinois.

Her favorite memory was the cockroach lab with Fred Delcomyn, a professor of neuroscience and entomology, where she learned about physiology. "The entire class was focused on how electrolytes in the nerves trigger muscle function," Elser said. "Although it is one of my favorite memories, it was also scary because some of the cockroaches were bigger than my hand."

After graduating in 1984, Elser returned to Chicago and joined the Rush University Medical Center where she joined the gynecology program. Over the years, Elser has maintained a balancing act between surgery and research, where she studies issues that are often overlooked by surgeons. She also works on projects that solve surgical problems using engineering techniques.

The same spirit of innovation drew Elser to the IGB labs, where she was particularly impressed with the EIRH theme, which focuses on improving reproductive health. Her donation will help the research groups develop tools to investigate how environmental toxins can impact reproductive health.

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Joseph Irudayaraj
Xing Wang

IGB
CGD
EIRH
MME

Winners of the Mikashi Awards announced

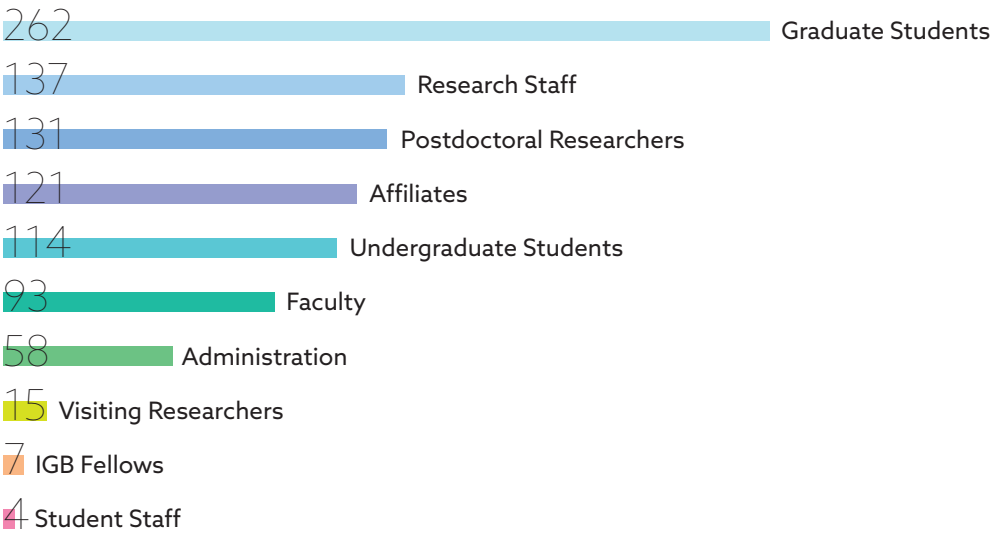
The Proof-of-Concept Program, named the Mikashi Awards, is funded by the Catherine and Don Kleinmuntz Center for Genomics in Business and Society to support IGB faculty. The 2021 winners are Joseph Irudayaraj, a Founder Professor in Bioengineering, and Xing Wang, a Research Associate Professor of Chemistry. The awards will help them bridge the funding "gap" between government-supported innovations that result from university research and the private sector support which converts these innovations into commercial products.

Wang's project will involve creating a rapid, sensitive, and cheap virus-sensing technology with DNA nanostructures. These structures can recognize and capture viral particles and emit a fluorescent signal, which can be read instantly with lab equipment. The method circumvents the tedious process of extracting and purifying nucleic acid material from the virus. Using the award, the lab will continue developing probes to detect influenza and HIV in both a home setting and at medical diagnostic centers. The tests will take less than ten minutes and will cost less than $0.50 per test.

Irudayaraj will work to treat retinal artery occlusion, a condition where the retinal arteries are blocked resulting in irreversible blindness. He will use oxygen nanobubbles to deliver the gas and thereby preserve the retinal tissues. Irudayaraj hopes that the FDA approval could be expedited because the condition is characterized as an orphan disease—the number of cases is less than 200,000 in the USA. The funding from the awards will help the team collect data and submit an Investigational New Drug application to the FDA.

2021 Numbers, Publications, and Awards

People



Total 942

Economic Development

Re-Writable DNA-Based Digital Storage with Random Access, Huimin Zhao, Olgica Milenkovic

Recombinant Microorganisms with Mixed Sugar Utilization, Yong-Su Jin

Biosynthesis of Oligosaccharides, Yong-Su Jin

Small Molecules Active Against Gram-Negative Bacteria, Paul Hergenrother

Publications

1085 papers published, 12 in *Science* and *Nature*

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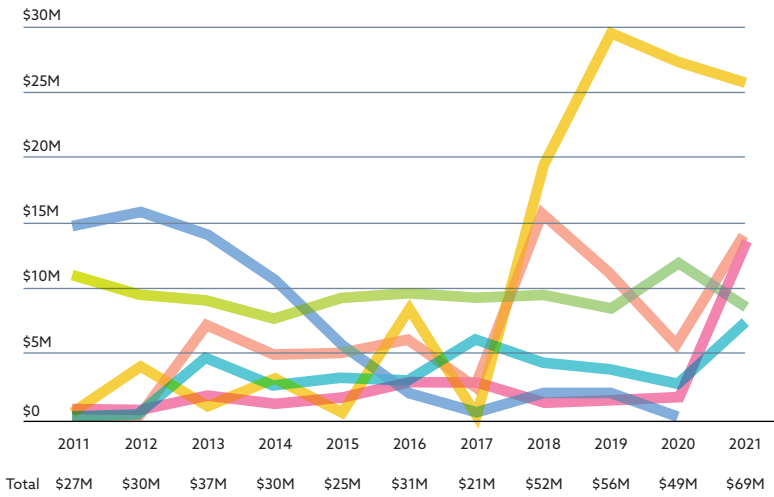
Core Facilities

Research Groups

Active Users

Grant Awards



DOE
$25,782,545

Bill & Melinda Gates Foundation
$14,144,996

NSF
$13,693,479

NIH
$8,480,466

Others
$7,394,129

FY21 Total
$69,495,615

Outreach

2500+
people reached

55
outreach events and programs

13
community partner organizations

90
volunteers

188 hours
outreach activities

12
campus collaborating units

1-70+
ages reached

491
volunteer hours

Awards

Lisa Ainsworth, research plant physiologist with USDA-ARS, adjunct professor of plant biology and crop sciences (CABBI/GEGC), received Distinguished Senior Research Scientist of the Year, 2021.

Brian Allan, Professor of Entomology (IGOH), appointed inaugural IGB Director's Faculty Fellow for 2021-2022.

William Barley, Associate Professor of Communication, appointed inaugural IGB Director's Faculty Fellow for 2021-2022.

Rashid Bashir, Professor of Bioengineering and Dean of the Grainger College of Engineering (CGD/M-CELS), awarded American Institute for Medical and Biological Engineering's 2021 Professional Impact Award for Education.

Alison Bell, Professor of Evolution, Ecology, and Behavior (GNDP leader), elected Fellow of Animal Behavior Society.

May Berenbaum, Professor and Head of Entomology (GEGC/IGOH), named Director of the Center for Advanced Study, Illinois.

Rohit Bhargava, Founder Professor in Bioengineering (CGD), named to *The Analytical Scientist*'s 2021 Power List.

Marni Boppart, Professor of Kinesiology and Community Health (RBTE), named Fellow of the American Physiological Society.

Christopher Brooke, associate professor of microbiology (IGOH), received the Presidential Medallion.

Martin Burke, May and Ving Lee Professor for Chemical Innovation and Professor of Chemistry (MMG), elected to The American Society for Clinical Investigation; received the Presidential Medallion.

Brian Cunningham, Donald Biggar Willett Professor of Engineering and Professor of Electrical and Computer Engineering (CGD Theme Leader/MMG), received 2021 Everitt Teaching Award for Teaching Excellence, Grainger College of Engineering.

Mohammed El-Kebir, Assistant Professor of Computer Science (IGOH), received NSF CAREER Award.

Timothy M. Fan, professor of veterinary clinical medicine (ACPP/CGD), received the Presidential Medallion.

Martha Gillette, Alumni Professor of Cell and Developmental Biology (GNDP/M-CELS), received 2021 Vision and Spirit Award from Beckman Institute.

Hee-Sun Han, Assistant Professor of Chemistry (IGOH/GNDP), received 2021 WISTEM2D (Science, Technology, Engineering, Math, Manufacturing, and Design) Scholar Award from Johnson & Johnson.

Brendan Harley, Robert W. Schaefer Professor, Chemical & Biomolecular Engineering (RBTE Theme Leader/EIRH), awarded Clemson Award for Basic Research from Society For Biomaterials.

Mark Hauber, Harley Jones Van Cleave Professor of Host-Parasite Interactions, Evolution, Ecology, and Behavior (GNDP), appointed Center for Advanced Study Associate.

Paul J. Hergenrother, Kenneth L. Rinehart Jr. Endowed Chair in natural products chemistry (ACPP leader/MMG), received the Presidential Medallion.

Joseph Irudayaraj, Founder Professor of Bioengineering (CGD/EIRH), named 2021 Fellow of the International Academy of Medical and Biological Engineering (IAMBE); selected as Fellow of Royal Society of Chemistry.

Stephen Long, professor of crop sciences and plant biology (BSD/CABBI/GEGC), named to the Clarivate Analytics Highly Cited Researchers list .

Zeynep Madak-Erdogan, Associate Professor of Nutrition (CGD/EIRH/GSP), named Editor-in-Chief of the *Journal of the Endocrine Society.*

Korinta Maldonado, Assistant Clinical Professor of Anthropology (IGOH), received 2021 Immigrant Leadership Award from Champaign-Urbana Immigration Forum.

Ripan Malhi, Professor of Anthropology (GNDP/GSP/IGOH), received Robert W. Sussman Award for Scientific Contributions to Anthropology from AAAS Steering Group of Section H; named 2021-22 Levenick Institute for Sustainability, Energy, and Environment Teaching Sustainability Fellow.

Sergei Maslov, Professor and Bliss Faculty Scholar of Bioengineering (BCXT/CABBI), elected Fellow of American Institute for Medical and Biological Engineering; received the Presidential Medallion.

Ruby Mendenhall, Associate Professor of Sociology (GNDP), received 2021 Pearl Birnbaum Hurwitz Humanism in Healthcare Award from Arnold P. Gold Foundation; named to Outstanding Faculty and Staff category, 9th Annual Diversity and Social Justice Education Awards, Illinois Office of Inclusion and Intercultural Relations.

Jeffrey Moore, Professor of Chemistry and Materials Science & Engineering (BSD), awarded Campus Executive Officer Distinguished Leadership Award.

Satish Nair, Department of Biochemistry Head (MME/MMG), appointed inaugural Gregorio Weber Endowed Chair of Biochemistry.

Donald Ort, professor of plant biology (GEGC leader/CABBI/BSD), named to the Clarivate Analytics Highly Cited Researchers list.

Gene Robinson, Swanlund Chair, Professor of Entomology (Director/GNDP), elected Member of the American Philosophical Society.

Rebecca Smith, associate professor of epidemiology (IGOH), received the Presidential Medallion.

Jonathan Sweedler, James R. Eiszner Family Endowed Chair in Chemistry (BSD/CABBI/MMG), named to Analytical Scientist's 2021 Power List.

Wilfred van der Donk, Richard E. Heckert Endowed Chair in Chemistry (MMG), elected to National Academy of Sciences.

Cari Vanderpool, Professor and Associate Head of Microbiology (IGOH/MME), elected Fellow of the American Academy of Microbiology.

Wendy Yang, Associate Professor of Plant Biology (CABBI/GEGC), received College of Liberal Arts & Sciences Dean's Award for Excellence in Undergraduate Teaching.

Icons

Technology and Society

Research that imagines, develops, and refines new tools that enable discovery and create solutions to worldwide challenges.

Health and Wellness

Research that seeks to understand the origins and mechanisms of disease and discovers new ways to promote wellbeing.

Agriculture and Environment

Research that explores and protects ecosystems, especially those we rely on for food and fuel.

Abbreviations

ACPP	Anticancer Discovery from Pets to People
BCXT	Biocomplexity
BSD	Biosystems Design
CABBI	Center for Advanced Bioenergy and Bioproducts Innovation
CGD	Center for Genomic Diagnostics
EIRH	Environmental Impact on Reproductive Health
GEGC	Genomic Ecology of Global Change
GNDP	Gene Networks in Neural and Developmental Plasticity
GSE	Genome Scale Engineering Center
GSP	Genomic Security and Privacy
IGOH	Infection Genomics for One Health
M-CELS	Multi-Cellular Engineered Living Systems
MME	Microbiome Metabolic Engineering
MMG	Mining Microbial Genomes
RBTE	Regenerative Biology and Tissue Engineering

Acronyms

DOE	Department of Energy
EPA	Environmental Protection Agency
IGB	Carl R. Woese Institute for Genomic Biology
NASA	National Aeronautics and Space Administration
NIH	National Institutes of Health
NSF	National Science Foundation
USDA	United States Department of Agriculture

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