The Sciences

at Georgia Institute of Technology

THE EDGE/

of discovery and solutions for a healthier people and planet •

Annual Research & Community Review

Georgia Tech
College of Sciences

YEAR IN REVIEW

July 2021 - August 2022

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Special Thanks

W. Clayton "Clay" Sparrow Jr. (PHYS '68)

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Assistant Dean for Teaching Effectiveness
Principal Academic Professional in the School of Chemistry and Biochemistry

J. Cameron Tyson (CHEM '92, '97)

Assistant Dean for Academic Programs
Principal Academic Professional in the School of Chemistry and Biochemistry

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The idea that science is advanced by solitary geniuses is a myth that has been largely debunked. Instead, scientific progress is grounded and nourished by sustained collaborative effort. Scientists inspire and teach each other; we work across teams to observe and measure; we collectively formulate theories and make discoveries; and we innovate in a shared goal to foster a healthier people and planet.

We have generations of scientists to thank for advances in mathematics, physics, chemistry, biology, psychology, and earth sciences that have yielded new frontiers in our knowledge of this world we all share. Discovery, at the heart of scientific endeavors, continues apace — at the smallest imaginable scales, to those that define the edge of our universe. Discovery science remains the inspiration that spans millennia of progress.

Yet scientists today are also compelled to more completely embrace solution-based science. In the face of significant challenges posed by our modern world — increasingly severe weather events, sea level rise, the loss of biodiversity and habitat, the ubiquity of pandemics and disease, and the rapid proliferation of emerging technologies — we understand that a transformation is needed in how we make progress in solving these challenges.

Progress in our quest to find solutions will result only from expanding partnerships more fully within — and with those outside of — our scientific community. We must reach out to engineers, entrepreneurs, and social scientists to develop and guide rapidly changing fields such as artificial intelligence, bioengineering, and climate adaptation and mitigation. Furthermore, success in this realm will be marked by scientific advances and by the extent to which our work ensures equitable outcomes for everyone. Progress must be partnered with fairness.

Progress will also be possible only if the students in our classrooms and laboratories understand the power of science to fuel discovery *and* its power to fuel solutions. The next generation of ideas that will change our world are now germinating in the minds of our students. Ours is the duty to inspire, support, and mentor those who will pick up the baton in this work to create a better world.

Here in the College of Sciences at Georgia Tech, the foundation that guides these efforts is our 2021-2030 Strategic Plan, which provides a scaffolding to support our mission, vision, and goals over this decade and those ahead.

The main goals of our plan — excellence in the workplace, in education and training, and in our research endeavors — are enveloped by three themes: catalyze discovery and solutions, amplify impact, and build communities of excellence. Our research and education priorities are structured to accomplish strategic goals that are focused on collaboration and team science, interdisciplinary inquiry, equity and inclusion, and cultivating the next generation to lead in science and society.

At the heart of that plan and in these pages, you will see highlights of the people, partnerships, and organizations that collectively create our story. Woven throughout these pages you will find the core character of our College and Institute: knowledge, progress, and service.

As we keep our minds, hearts, and hands trained on developing leaders, creating solutions, and improving the human condition — I invite you to explore this space and join us in this work.

M. Susan Lozier

Dean and Betsy Middleton and John Clark Sutherland Chair

Professor in the School of Earth and Atmospheric Sciences

College of Sciences at Georgia Tech

President, American Geophysical Union

cos.gatech.edu

Leadership News

Academic, Administrative, and Research Excellence

Since the start of fiscal year 2022, the College of Sciences has welcomed a number of new leaders to campus and recognized the promotion of several faculty and staff to existing and newly created leadership roles at Georgia Tech — including several endowed faculty distinctions made possible thanks to the support of our alumni, friends, and foundations. Please join us in welcoming and celebrating these members of our community.

New leadership appointments are shown in bold, *across our past fiscal year (July 1, 2021 to June 30, 2022) and academic year (Fall 2021, Spring 2022, and Summer 2022 semesters).*
(i) marks inaugural leaders *of newly created roles at Georgia Tech.*

Institute Leadership

Julia Kubanek

Vice President for Interdisciplinary Research (VPIR)
Georgia Institute of Technology
Professor, School of Biological Sciences and School of Chemistry and Biochemistry

College Leadership

Kimberly Blaise

Assistant Director
Explore Living Learning Community (LLC)
College of Sciences

Laura Cadonati

Associate Dean for Research
College of Sciences
Professor, School of Physics

Jennifer Leavey

Assistant Dean for Faculty Mentoring
College of Sciences (i)
Principal Academic Professional
School of Biological Sciences
Director, Georgia Tech Urban Honey Bee Project

Jean Lynch-Stieglitz

Georgia Tech ADVANCE Professor
Professor, School of Earth and Atmospheric Sciences

Carrie Shepler

Assistant Dean for Teaching Effectiveness
College of Sciences (i)
Principal Academic Professional
School of Chemistry and Biochemistry

Lewis Wheaton

Director, Center for Promoting Inclusion and Equity in the Sciences (C-PIES)
College of Sciences (i)
Associate Professor
School of Biological Sciences

Tara Holdampf
Satellite Counselor
College of Sciences and Georgia Tech Counseling Center (i)

James Stringfellow
Career Educator
College of Sciences and Georgia Tech Career Center (i)

Satellite Counselor Supports Student Well-Being and Mental Health

In Fall 2021, the College of Sciences and Georgia Tech Counseling Center welcomed **Tara Holdampf** as the College's first satellite counselor. In this newly created role, Holdampf provides consultation services and support for students both remotely and in person, with an office in the Molecular Science and Engineering Building.

"I'm excited to join the incredibly welcoming and talented group at the College of Sciences at Georgia Tech as a satellite counselor," Holdampf said, "to continue the process of breaking down barriers between students and mental health services."

Placing a counselor in an academic department helps to destigmatize mental health and may serve those who might hesitate to go to the Georgia Tech Counseling Center. A primary goal is to reach students who might not have otherwise sought out services.

Holdampf also provides a wide variety of services such as individual counseling, group counseling, psycho-educational workshops, and walk-in hours. She also offers students, faculty, and staff the opportunity to learn more about mental health resources on campus, and to discuss specific non-emergency student concerns.

Holdampf has an M.S. in Clinical Mental Health Counseling and is a Licensed Professional Counselor in Georgia. She is also a Certified Clinical Trauma Professional and serves on the Council of the Georgia College Counseling Association.

Sciences Hires First Career Educator

Sciences students kicked off 2022 with a new resource to help plan their careers: **James Stringfellow**, jointly appointed by the College of Sciences and Georgia Tech Career Center as the College's first career educator.

An employment specialist with a history of helping Atlanta-based veterans and entertainment industry staff in the workforce, Stringfellow helps students and instructors with career mapping, planning, and workforce preparedness.

His focus also includes co-ops and internships, as well as fostering College of Sciences programs by facilitating career education events, supporting instructors with employer updates and industry trends, developing employer partnerships to cultivate employment opportunities, and assisting the Career Center team in meeting its community goals.

Stringfellow previously worked for the Veterans Empowerment Organization (VEO) as an employment specialist assisting veterans with re-entry into the civilian workforce, in Atlanta with higher education health sciences programs, and as an award-winning career services manager at SAE Institute (School of Audio Engineering), which oversees employer outreach and graduate employment for audio, film, and entertainment business programs.

College of Sciences students at Stringfellow's "Meet Your Career Educator" event, held this fall.

School Leadership

Tansu Celikel

Chair and Professor
School of Psychology
Former Chair and Professor
Department of Neurophysiology
Radboud University

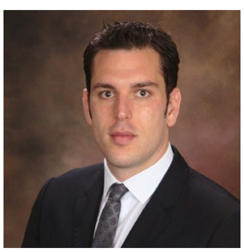
Feryal Özel

Chair and Professor
School of Physics
Former Professor of Astronomy and Physics and Associate Dean for Research, College of Science
University of Arizona

Michael Wolf

Chair and Professor
School of Mathematics
Former Milton B. Porter Professor in Mathematics
Rice University

Faculty Distinctions

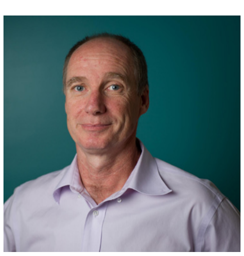


Jason Azoulay

Georgia Research Alliance (GRA) Distinguished Investigator (i)
Incoming Associate Professor and Vasser Woolley GRA Distinguished Investigator in Sensors and Instrumentation, School of Chemistry and Biochemistry, with a joint appointment in the School of Materials Science and Engineering

Facundo Fernández

Regents' Professor (2022)
Vasser Woolley Professor and Associate Chair for Research and Graduate Training, School of Chemistry and Biochemistry



Greg Gibson

Regents' Professor (2021)
Tom and Marie Patton Chair
College of Sciences
Co-Director, CHOA Center for Immunity and Applied Genomics

Lynn Kamerlin

Georgia Research Alliance (GRA) Eminent Scholar
Incoming Professor and Vasser Woolley GRA Eminent Scholar Chair in Molecular Design, School of Chemistry and Biochemistry

Joseph Montoya

Director, Interdisciplinary Ph.D. Program in Ocean Science and Engineering (OSE)
Professor, School of Biological Sciences

Charles David Sherrill

Regents' Professor (2021)
Professor, School of Chemistry and Biochemistry with a joint appointment in the College of Computing

Faculty Endowments

Nicholas Hud

Julius Brown Professor of Chemistry and Biochemistry
Regents' Professor, School of Chemistry and Biochemistry

Svetlana Jitomirskaya

Elaine M. Hubbard Chair
School of Mathematics (i)
Former Distinguished Professor in Mathematics, University of California, Irvine

Raquel Lieberman

Kelly Sepcic Pfeil, Ph.D. Chair (i)
Professor, School of Chemistry and Biochemistry

Martin Mourigal

Blanchard Early Career Professor (i)
Associate Professor
School of Physics

Yuanzhi Tang

Blanchard Early Career Professor (i)
Associate Professor
School of Earth and Atmospheric Sciences

Dobromir Rahnev

Blanchard Early Career Professor (i)
Associate Professor
School of Psychology

Joshua Weitz

Tom and Marie Patton Chair, School of Biological Sciences
Blaise Pascal International Chair of Excellence
Institute of Biology at the École Normale Supérieure (IBENS)
Professor, School of Biological Sciences

Celebrating Excellence

Joined by alumni and friends, over the past academic year the College welcomed new professors at two outdoor receptions. The **September 2021 Sciences Celebration** also honored faculty award recipients, and highlighted excellence in research, teaching, and scholarship with awards made possible by the generosity of our donors. The **Spring 2022 Sciences Celebration** also included the presentation of annual faculty honors alongside the College's first annual staff and research faculty awards in recognition of individual excellence and community accomplishments.

At the annual **Georgia Tech Diversity Symposium**, held in September 2021, **Lewis Wheaton** was named the Institute's Faculty Diversity Champion, and seven College of Sciences staff and faculty were chosen as Faces of Inclusive Excellence. Wheaton, an associate professor in the School of Biological Sciences, was appointed director of the new Center for Promoting Inclusion and Equity in the Sciences (C-PIES) for the College of Sciences in August 2022.

Georgia Institute of Technology

COLLEGE OF SCIENCES

by the numbers

6 SCHOOLS

- Biological Sciences
- Chemistry and Biochemistry
- Earth and Atmospheric Sciences
- Mathematics
- Physics
- Psychology

11 interdisciplinary programs

HOME TO **40+** student organizations

Neuroscience, Georgia Tech's fastest growing undergraduate program

EXPLORE LLC
Pre-health- and research-focused Living and Learning Community

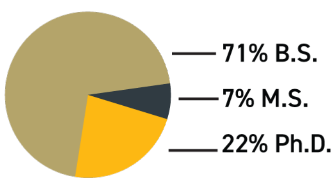
(FY22)

$60.5M in research expenditures and **$61.3M** in new research funding

6 NSF-funded **Research Experiences for Undergraduates** (REU) programs

3,115 enrollments (FY22)

↑4% from FY21



671 degrees awarded (AY21-22)

63% B.S.
19% M.S.
18% Ph.D.

52% of all degrees awarded to **women**

GEORGIA TECH 2022 FIRST-YEAR ADMISSIONS SNAPSHOT

50,601 total applications

↑12% from FY21

↑53% in first-gen applications

11% total admitted students are *first generation*

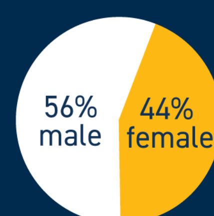
21% total admitted students identify as **Black** or **Hispanic**

112 Georgia counties

50 states + D.C. and P.R.

102 nations

21% of total admitted students are in the College of Sciences



THE EDGE *of astrophysics and planetary sciences*

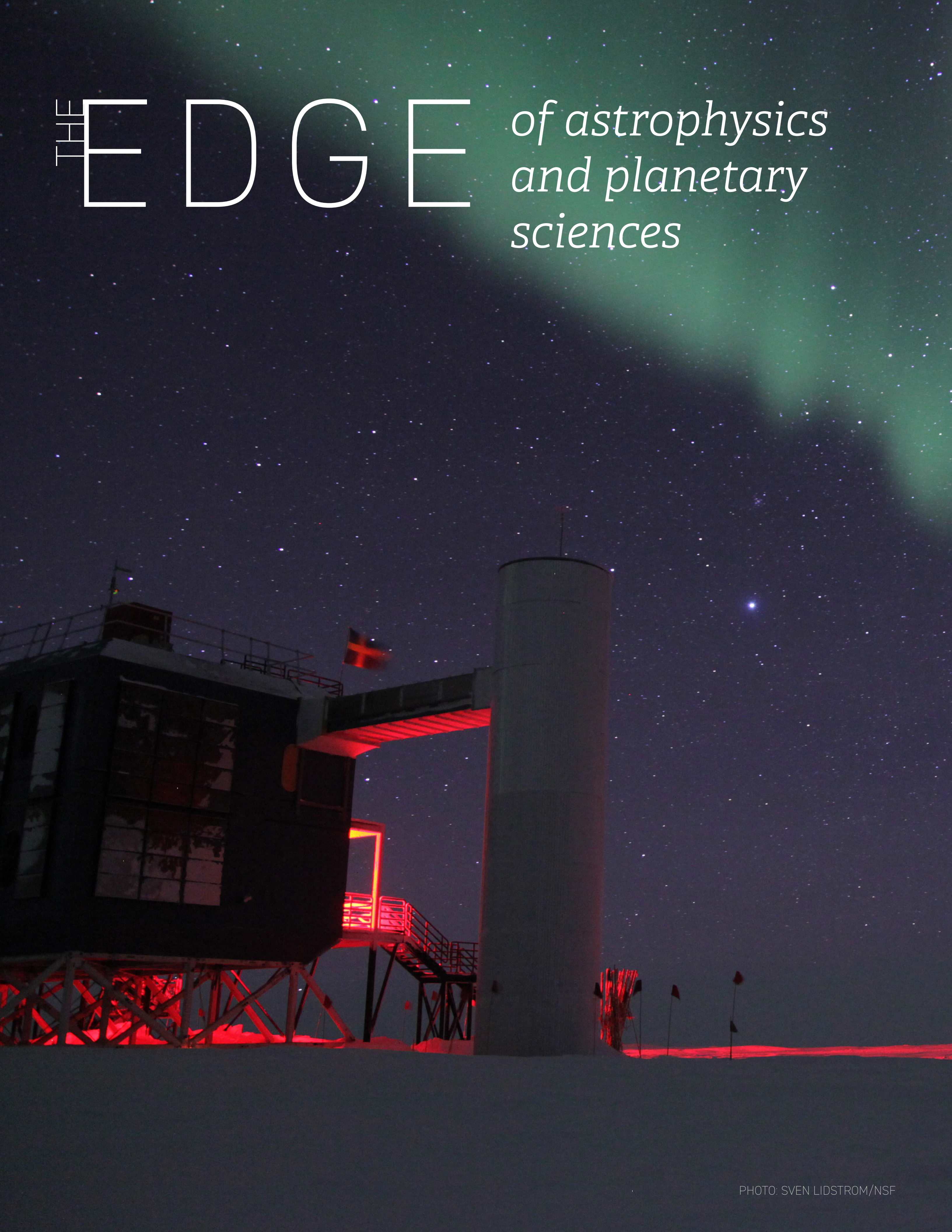
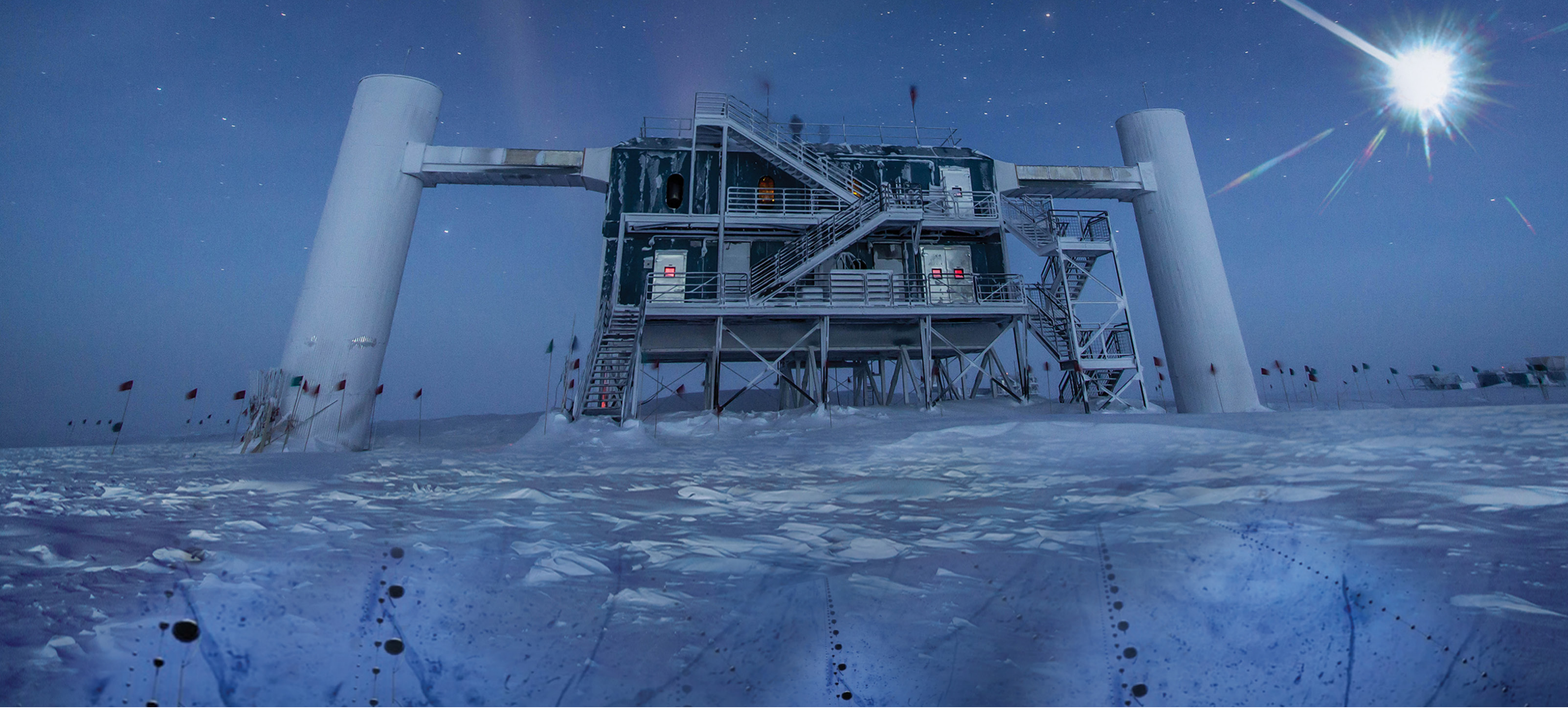


PHOTO: SVEN LIDSTROM/NSF



Ignacio Taboada Elected Spokesperson for IceCube South Pole Neutrino Observatory

Ignacio Taboada, a professor in the School of Physics and member of the Center for Relativistic Astrophysics at Georgia Tech, began his term in May 2021 as spokesperson for the IceCube Neutrino Observatory, a collective of more than 300 scientists worldwide who work to detect neutrinos and other high-energy streams of subatomic particles reaching Earth from deep space.

"I think the relevance is that big science, as understood in terms of large scientific collaborations, is now clearly an important part of the scientific portfolio at Georgia Tech," Taboada said. "I really hope that this is a sign of more things to come for physics and for science in general — and I really am very hopeful that Georgia Tech is going to play a big role within Gen2 (the next phase of IceCube's development)."

The system of sensitive detectors has already yielded major discoveries about neutrinos. "We keep just pushing the frontier," said **Darren Grant**, the outgoing spokesperson for IceCube. "We clearly haven't reached the limit of what this instrument can do."

"[W]e're beginning to get close to measuring neutrinos from our own galaxy, the galactic plane, and that will be a really beautiful result," Taboada added. "We believe our astrophysical neutrinos are extragalactic, but I think we may be close to seeing the galaxy as a whole, maybe. That's a long shot, but not impossible." • MADELEINE O'KEEFE

"Big science, as understood in terms of large scientific collaborations, is now clearly an important part of the scientific portfolio at Georgia Tech."

–Ignacio Taboada, School of Physics

Section cover: The aurora australis shines above NSF's IceCube Neutrino Observatory at NSF's Amundsen-Scott South Pole Station. Above: In this artistic composition, based on a real image of the IceCube Lab at the South Pole, a distant source emits neutrinos that are detected below the ice by IceCube sensors, called DOMs. ICECUBE/NSF

Two suited crew members work on the lunar surface. One in the foreground lifts a rock to examine it while the other photographs the collection site in the background.
ILLUSTRATION: NASA

The Future of Space Exploration

New things are happening above Earth's atmosphere: tourists can pay private companies for a trip to space, private industry is developing spacecraft for NASA missions, and a robotic helicopter is exploring Mars. NASA's Artemis program has set a goal of landing humans on the Moon in 2025 to begin building a base camp, with exciting implications: long-term human presence on the lunar surface will help NASA prepare for human space exploration missions of greater distance and duration, including an eventual crewed flight to Mars.

The role of lunar ice

"Nobody knows where or how much lunar ice is on the Moon, and this could be hugely important for human space exploration," explained **Glenn Lightsey**, a professor in the Daniel Guggenheim School of Aerospace Engineering (AE) and co-principal investigator for the Lunar Flashlight project, a collaboration between Georgia Tech engineers and researchers and NASA's Jet Propulsion Laboratory (JPL) to assemble, integrate, and test a small satellite that will gather information regarding lunar ice.

The information could tell scientists more about lunar chemistry and planetary origins, potentially uncovering pre-biotic molecules. Additionally, the ice could provide millions of gallons of water, which could sustain human life during planetary travel, or could be used to make fuel.

Mission control for Lunar Flashlight will be run out of Lightsey's lab on Georgia Tech's campus. "Running this mission and building this spacecraft is a tremendous opportunity for Georgia Tech," said Lightsey. "It really puts us in the space arena as a world-class enterprise that can carry out missions for NASA. There are very few places that can do this kind of work."

"The presence of water on the Moon is of tremendous importance from both a fundamental science point of view and a practical perspective. It is a topic that links lunar science and exploration," said **Thomas Orlando**, a professor in the School of Chemistry and Biochemistry and principal investigator for the Radiation Effects on Volatiles and Exploration of Asteroids and Lunar Surfaces (REVEALS) team that is dedicated to researching topics for future human space exploration.

Engineering hardware with scientific instrumentation

Orlando's work with REVEALS is a perfect example of interdisciplinary research at Georgia Tech: REVEALS is researching ways to prepare NASA for the next generation of its crewed space missions, and is, itself, part of a larger NASA program, SSERVI (Solar System Exploration Research Virtual Institute).

The project includes designing spacesuits with radiation detection materials sewn into the suits — and using the Moon's natural resources to support astronaut habitats.

"REVEALS is focusing on the water on the Moon issue. This involves understanding how it is made or delivered, how it is transported, and where it is. The work also involves developing technologies to extract it, a project led by **Peter Loutzenhiser** (George W. Woodruff School of Mechanical Engineering). We obviously need to know how much is there and whether we can get it and utilize it. This is where Lunar Flashlight comes in," Orlando said.

The interdisciplinary connection

The Moon is about 240,000 miles away from Earth – almost 1,000 times further away than the International Space Station (ISS). While travel between the ISS and Earth currently takes a few hours, astronauts might take three days to return home from the Moon. This poses a unique logistical and technical challenge.

Mission Control for Lunar Flashlight operations at Georgia Tech. From left to right: Ulises Núñez, Kathleen Hartwell, Sterling Peet, Jud Ready, and Glenn Lightsey. CANDLER HOBBS

"The spacecraft and life support systems will have to manage themselves at a greater level than what we have now," said **Sandy Magnus**, a former NASA astronaut and professor of practice at Georgia Tech. "Currently an army of folks in mission control on Earth track a host of system functions. But if you can build good autonomous systems, they will track themselves."

New technologies will require multidisciplinary expertise. "It's not just you have an avionics problem, or a thermal problem, or a materials problem, it's normally much more complex than that," explained Magnus, who received her Ph.D. from Georgia Tech's School of Materials Science and Engineering in 1996. "One of the strengths that Georgia Tech brings to the whole enterprise is the fact that its campus has a lot of cross-disciplinary and multidisciplinary research."

Earth's moon, Mars, and beyond

From Earth, to the Moon, to Mars and beyond, scientists are forging paths into the future of space exploration through interdisciplinary collaboration and innovation.

Professor **Stephen Ruffin**, associate chair for Undergraduate Programs in AE, said that continuing to push the boundaries beyond Earth will spur new technologies and industries that will benefit society, while helping the U.S. maintain its lead in the space arena. "Going to the Moon and Mars will allow for amazing science to be conducted," said Ruffin. "We'll be able to learn more about the history of our solar system, understand what's happening to our planets, and create a better world for us here on Earth."

School of Earth and Atmospheric Sciences Associate Professor **Jennifer Glass** agrees. "Discovering life beyond Earth would fundamentally change humanity's perspective on our place in the universe," Glass said, flagging interdisciplinary collaboration as key. "Integrating astrobiology – the search of life in the universe – into space missions in order to know if and when we detect life on other planetary bodies, including exoplanets, is an exciting challenge currently underway."

The future of space exploration is vast, exciting, and rapidly developing, but one thing stands out as clear: Georgia Tech's students are ready to rise to the challenge. "Almost half of my students are getting a graduate degree in engineering and a graduate degree in science," Orlando said. "It markets them much more for SpaceX or NASA. It's this hybrid training that people are looking for, and I can't think of a better place for it than Georgia Tech." • CANDLER HOBBS

Surfing Gravitational Waves

Georgia Tech students help LIGO catalog all known space-time ripples

An international collaboration of scientists, including a team of Georgia Tech graduate students, undergraduate students, and faculty, have released the largest catalog ever of gravitational waves from cosmic collisions of black holes and neutron stars.

Their findings, which include the detection of 35 new gravitational wave events since the last release in October 2020 — along with confirmation of intermediate-sized black holes, rare black hole-neutron star merges, and more information on extremely distant black holes — were published by the LIGO-Virgo-KAGRA Collaboration last November.

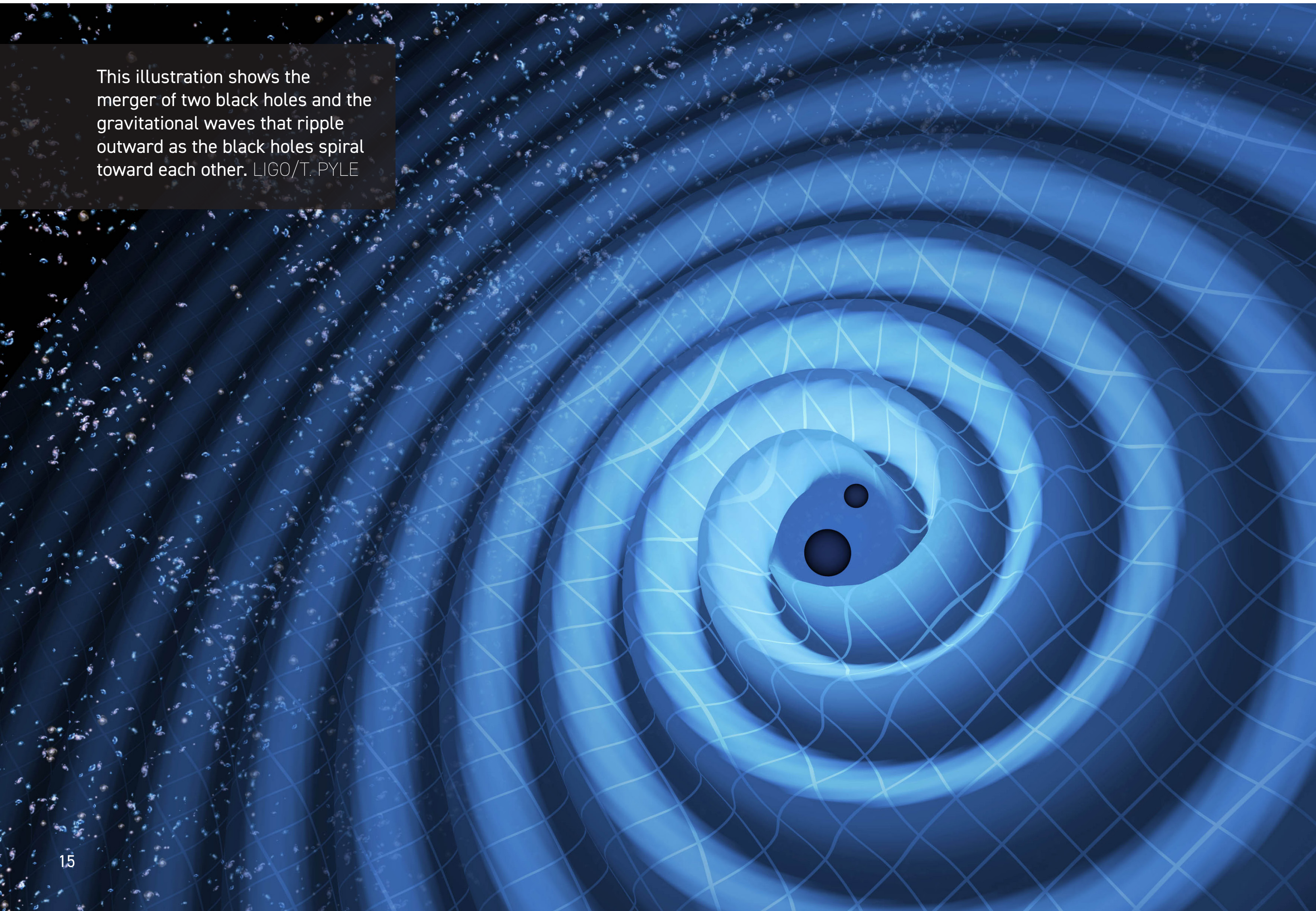
The research group included graduate students **Sudarshan Ghonge**, **Hannah Griggs, Megan Arogeti**, **Erin Thompson**, and **Peter Lott**.

Undergraduates **Joshua Brandt**, **Nadia Qutob,** and **Jack Sullivan** are co-authors of the paper summarizing the gravitational wave findings.

The students were supervised by **Laura Cadonati**, associate dean for Research in the College of Sciences. Cadonati is also a professor in the School of Physics and former director of the Center for Relativistic Astrophysics, as well as a former LIGO (Laser Interferometer Gravitational-Wave Observatory) deputy spokesperson.

"It is amazing to get involved in this type of research so early on" as an undergraduate, said Brandt, now a third-year student in the School of Physics. "A lot of this cutting-edge research isn't just individuals with specialized knowledge all combining their results together; it thrives on willingness of experienced scientists to share their knowledge and teach those who want to become involved and contribute."

• RENAY SAN MIGUEL



This illustration shows the merger of two black holes and the gravitational waves that ripple outward as the black holes spiral toward each other. LIGO/T. PYLE

Plumes of Hot Material Near Earth's Core Grease Way for Moving Slabs of Earth

A recent study co-authored by **Samer Naif** and published in the journal *Nature* suggests that mantle plumes could be putting into place long-lived, water-rich melt in a network of thin channels at the base of Earth's rigid outer shell. This melt would help reduce viscosity and create a slippery base for the tectonic plates.

"Essentially, we developed computer codes that integrate thermodynamic modeling software with geophysical imaging software using a modern statistics-based approach," said Naif, who is an assistant professor in the School of Earth and Atmospheric Sciences.

The team found that melt channels could be a byproduct of mantle plumes globally. If an oceanic plate creeps past a plume, it could inherit melt channels and the unusually high volatile concentration needed to sustain its existence.

"This study demonstrates how we can advance our knowledge of Earth processes by combining different scientific disciplines," Naif said, citing collaboration as key to the study's success. In addition to Naif, the research team included **Daniel Blatter** of University of California, San Diego's Scripps Institution of Oceanography; **Kerry Key** of Columbia University; and **Anandaroop Ray** of Geoscience Australia.
• STEVE KOPPES

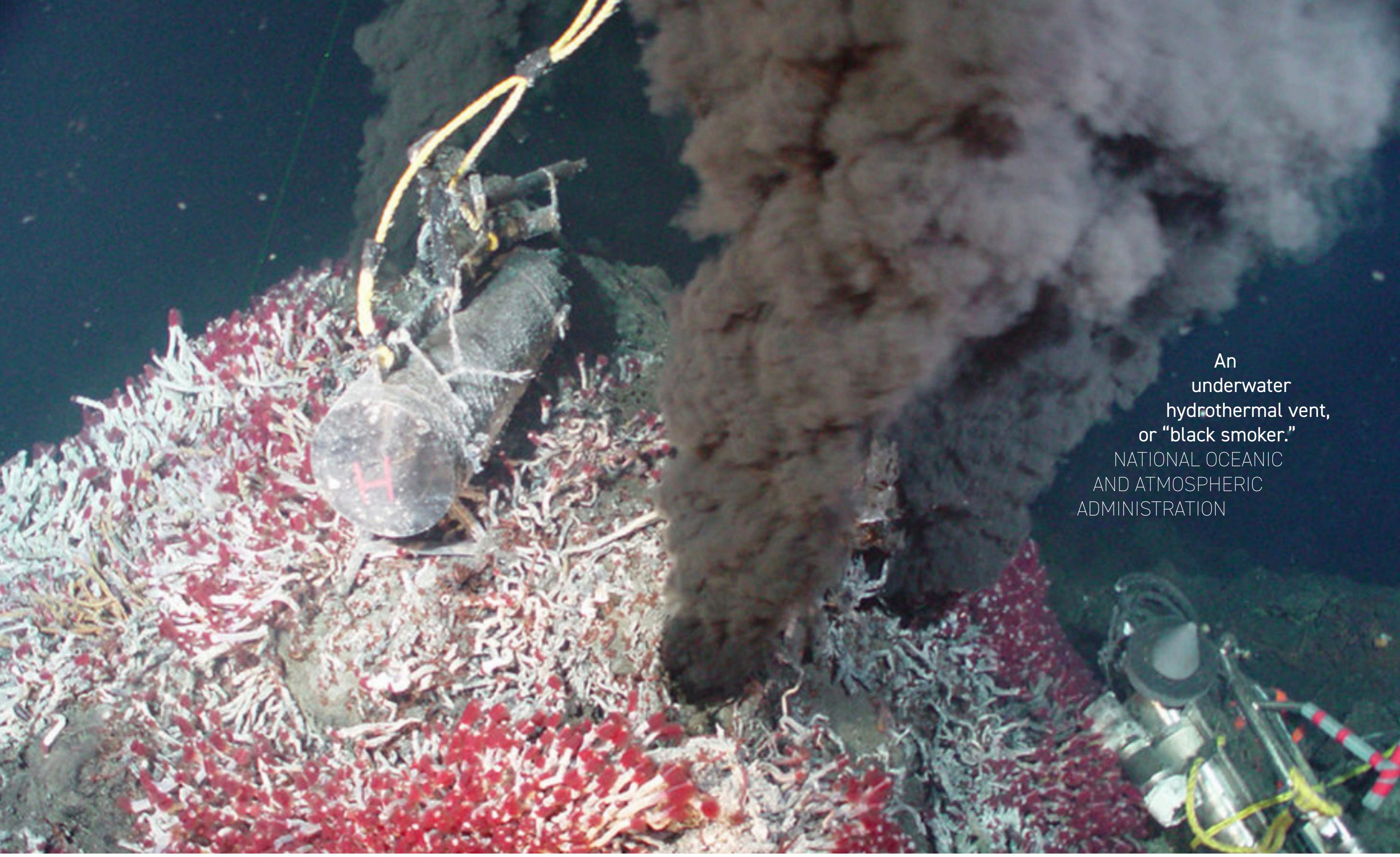
Researchers deploy an electromagnetic transmitter to study plate tectonics during a 2010 research expedition off the coast of Nicaragua. STEVEN CONSTABLE, SCRIPPS INSTITUTION OF OCEANOGRAPHY

Double Major Yashvardhan Tomar Receives 2022 Love Family Foundation Scholarship

Physics and aerospace engineering major **Yashvardhan Tomar** knew at an early age that he wanted to be a leading aerospace engineer and space scientist.

This May, he was selected to receive the 2022 Love Family Foundation Scholarship, awarded annually to a Georgia Tech graduating senior with the most outstanding academic record. It represents one of the highest academic honors given to an undergraduate student.

"I wish there were words sincere enough in the language to aptly convey how grateful I feel to the Institute," Tomar said, "to the administration, the college deans, and the members of the award committee — for choosing me, among so many promising candidates, for this high honor; to my department chairs **Stephen Ruffin**, **Graeme Kennedy**, and **Michael Schatz** for investing their faith in my candidature; to all my research mentors for always holding a lantern on the path forward; to my peers and family for always keeping me strong and resolute through testing times. And of course, I convey my most earnest gratitude to the Love family for bringing this glad, glad moment to life for me!" • CORY HOPKINS



An underwater hydrothermal vent, or "black smoker." NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Oceanic Phosphorus Lends Light to the Hunt for Habitable Worlds

An international team has found a new twist in Earth's oceanic nutrient cycles, adding new possibilities for a key building block of life on Earth and Earth-like planets beyond the solar system

When it comes to the chemical elements needed for life to begin — whether on the early Earth, or any number of rocky planets elsewhere in the universe that may be promising venues for life — the focus is usually on oxygen, carbon, and nitrogen. **Chris Reinhard**, an associate professor in the School of Earth and Atmospheric Sciences, offers a helpful reminder: don't forget about phosphorus.

"It's central to biochemistry for all life on Earth. It's an important component of nucleic acids and energy transduction in cells," said Reinhard, referring to other necessary building blocks for life. "When you're thinking about the kind of ingredients used to build life from non-life, it's one of the key components in that mix."

Previously, it was thought that continents above sea level were required for habitable planets to support a robust biosphere, because the phosphorus nutrient cycle starts on land and ends up in the ocean. "We used experimental geochemistry and a simple model of biological cycling to show that this is incorrect," Reinhard said, "which significantly expands the possible range of planets that may host surface biospheres that would be detectable through telescope observations."

Speed limits, sinks, and 'smokers'

The largest source of phosphorus on Earth is found in rocks in the planet's crust. On exposed continents above sea level, that phosphorus becomes available to the marine biosphere via continental weathering — the steady bombardment of environmental conditions like rain, extreme temperatures, and biological activity — that eventually releases phosphorus into the ocean via soils, rivers, and streams.

Phosphorus in nature is a limiting nutrient, acting as a brake on growth in the biosphere. "It's one of the reasons we're interested in phosphorus," Reinhard said. "Life also needs carbon and nitrogen and various trace elements, but it's phosphorus that really kind of sets the speed limits on the biosphere — the extent to which it can do what it does on a global scale."

Phosphorus can also come from hydrothermal vents on ocean floors, systems similar to the famous "black smokers" where seawater is heated to ultra-hot temperatures by liquid rock deep below the Earth and shot out through the seafloor. "When this happens, all kinds of interesting chemical reactions are going on," Reinhard said. "This is potentially a conduit for unlocking the phosphorus into the biosphere."

The problem, however, is that those vents also release a lot of iron at the same time. "What happens when you pump this super-hot sea water, with these dissolved goodies in it, into the bottom of an ocean that has a ton of oxygen in it, the way the modern Earth does? You essentially rust that iron," Reinhard explained. "One thing that rust is good at is scavenging and removing dissolved phosphate from solution. So these vents are actually stealing food from Earth's biosphere on the whole."

The consensus is that those hot seafloor vents act as phosphorus sinks, but Reinhard and his team may have found that just the opposite can happen under certain conditions. "Our results turn that on its head," he said. "In many respects, what we're suggesting is hydrothermal systems in many cases can be quite large potential sources of phosphorus, instead of sinks."

Chris Reinhard (center) samples marine sedimentary rocks during a 2016 study on phosphorus and the early Earth.
GEORGIA TECH

Oxic vs. anoxic

It all depends on whether that hydrothermal alteration of the seafloor is happening under oxic (oxygenated) or anoxic (oxygen-free) conditions.

If anoxic, that phosphorus could potentially be harvested, Reinhard said.

"We did some experimental work looking at the chemical reactions between ocean crust and anoxic seawater, and ended up finding a novel route towards the production of nutrient phosphorus," he explained.

The team did that by taking pieces of that ocean crust and incubating them at temperatures and pressures meant to mimic how that crust is changed by hydrothermal activity. "We used a novel isotope tracer method to track the degree that crust was being dissolved, and the rate materials were being released into solution," said Reinhard.

"We think this result is likely to reshape the way folks look at the evolution of nutrient cycling on Earth, how the capacity of the biosphere to produce oxygen has evolved over time, and the likelihood that life will be remotely detectable on other rocky planets."

Chris Reinhard, School of Earth and Atmospheric Sciences

The research team estimated the ratio between phosphorus release and carbon dioxide consumption in their findings. "This ratio is comparable to that of modern rivers, suggesting that submarine weathering under anoxic conditions is potentially a significant source of bioavailable phosphorus to planetary oceans," they said

The team's findings also mean that ocean-covered planets and moons could join rocky planetary bodies as potential targets for the next generation of orbiting telescopes and planetary probes looking for key elements and molecules like phosphorus, oxygen, and methane as clues to habitability.

Reinhard added: "We think this result is likely to reshape the way folks look at the evolution of nutrient cycling on Earth, how the capacity of the biosphere to produce oxygen has evolved over time, and the likelihood that life will be remotely detectable on other rocky planets." • RENAY SAN MIGUEL

Research supported by NASA. Published in Geophysical Research Letters.

Subterranean Investigations

Physicists at Georgia Tech and engineers at the University of California, Santa Barbara are exploring the shallow underground world with a burrowing soft robot. The technology not only enables new applications for fast, precise, and minimally invasive movement underground, but also lays mechanical foundations for new types of robots.

“Discovery of principles by which diverse organisms successfully swim and dig within granular media can lead to development of new kinds of mechanisms and robots that can take advantage of such principles,” **Daniel Goldman**, Dunn Family Professor of Physics at Georgia Tech, said. “And reciprocally, development of a robot with such capabilities can inspire new animal studies, as well as point to new phenomena in the physics of granular substrates.”

The researchers explored options including a vine-like soft robot that mimics the way plants navigate by growing from their tips, and options inspired by burrowing animals like the southern sand octopus.

Applications range from sample collection to exploration in low gravity environments. “We believe burrowing has the potential to open new avenues and enable new capabilities for extraterrestrial robotics,” said **Elliot Hawkes**, professor of mechanical engineering at UC Santa Barbara. Now, the team is working on a project with NASA to develop burrowing for the Moon or distant bodies like Enceladus, the sixth-largest moon of Saturn.
• SONIA FERNANDEZ

*Research for this paper was also conducted by **Mason Murray-Cooper**, **Yasemin Ozkan-Aydin**, and **Enes Aydin** at Georgia Institute of Technology. Research supported by NASA, NSF, the Army Research Office, and the Packard Foundation. Published in* Science Robotics.

This fast, steerable, burrowing soft robot was featured as the cover of *Science Robotics* in June 2021. UC SANTA BARBARA

Bernard F. Schutz Elected Fellow of the Royal Society

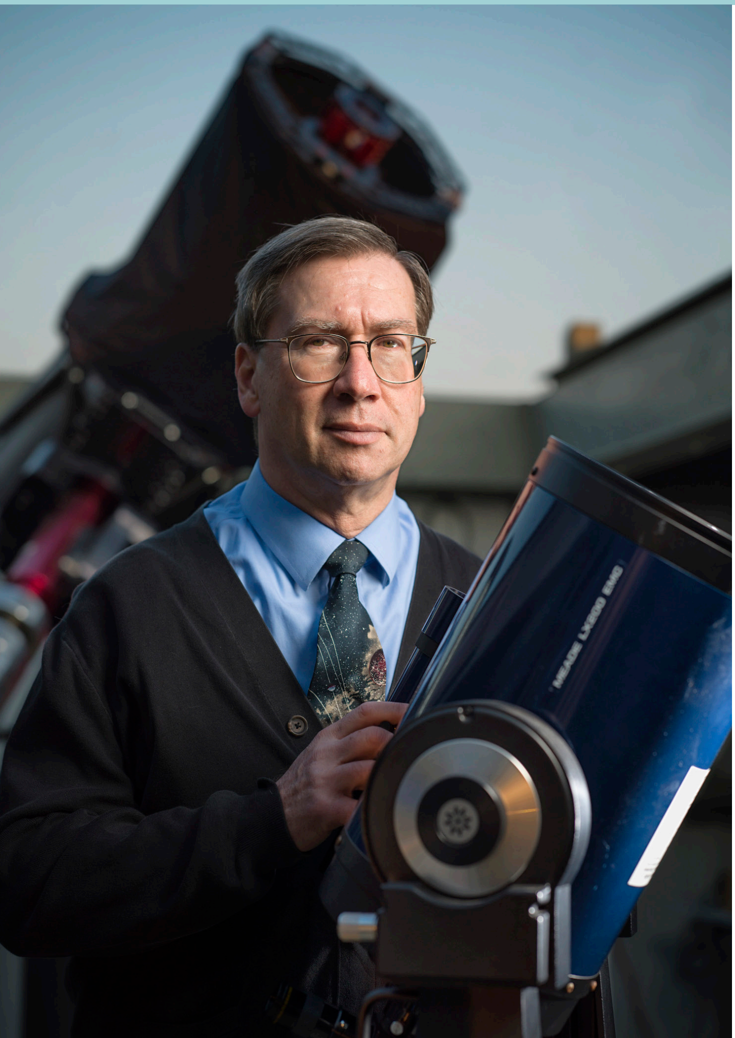
Bernard F. Schutz, an adjunct professor in the Georgia Tech School of Physics, has been elected as a Fellow to the Royal Society, the United Kingdom's national academy of sciences.

"It is wonderful to be recognized for work that started 35 years ago and still continues," Schutz said, "and it is humbling to be joining an academy that has such a distinguished membership."

Schutz's seminal contributions to relativistic astrophysics include driving the field for gravitational wave detection research, which helped lead to their direct detection in 2015. Georgia Tech played a pivotal role in the analysis of the observed signal, and gravitational wave confirmations earned the 2017 Nobel Prize in Physics.

Schutz has served as a founding director of the Max Planck Institute for Gravitational Physics (Albert Einstein Institute – AEI), helped spark the creation of the Center for Relativistic Astrophysics (CRA) at Georgia Tech, and laid the analytical foundation in the search for gravitational waves. He is also a professor in the School of Physics and Astronomy at Cardiff University.

"It is a great honor to have Professor Schutz as adjunct faculty to the CRA," said **Laura Cadonati**, College of Sciences associate dean for research, School of Physics professor, and past deputy spokesperson for the Laser Interferometer Gravitational-Wave Observatory (LIGO). "I think it is fair to say Professor Schutz is one of the founding fathers of multi-messenger astronomy — and the CRA is now part of that vision." • RENAY SAN MIGUEL

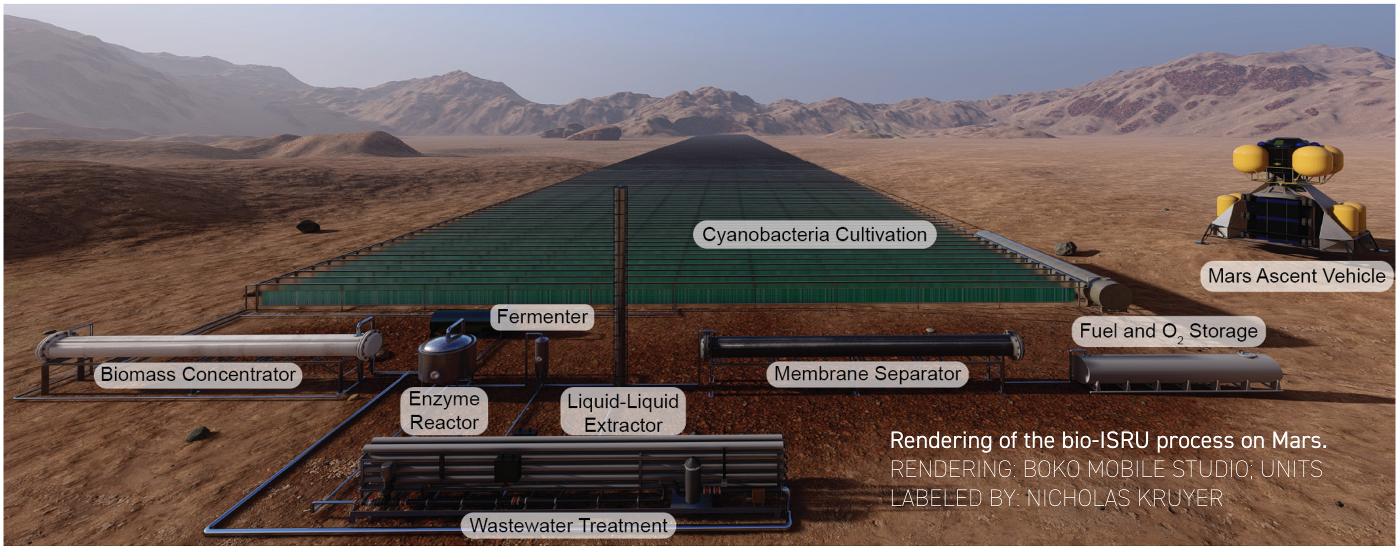


Public Nights Return to the Georgia Tech Observatory

Stargazers have returned to the Georgia Tech Observatory for public nights. On the grounds between the Howey and Mason Buildings, this year several telescopes were set up for viewing, and visitors were invited to bring their own telescope, as well.

Jim Sowell, principal academic professional and director of the Georgia Tech Observatory, is excited that public nights have returned after a break during the pandemic. "A clear evening with some celestial objects visible is as much a delight for me as it is for the visitors."

The viewing targets for this fall include the Moon, Jupiter, and Saturn. Sowell, along with members of the Georgia Tech Astronomy Club, will help answer questions and showcase various celestial objects. "I describe my role these days as a tour guide," said Sowell, "and I greatly enjoy hearing the squeals and gasps as people see craters on the Moon, or the rings of Saturn, or moons orbiting Jupiter." • VICTOR ROGERS



Rendering of the bio-ISRU process on Mars.
RENDERING: BOKO MOBILE STUDIO; UNITS LABELED BY: NICHOLAS KRUYER

Making Martian Rocket BioFuel on Mars

Researchers at Georgia Tech have developed a biotechnology-based *in situ* resource utilization (bio-ISRU) process to produce rocket fuel on Mars.

Making the propellant using Martian resources could help reduce mission cost. Additionally, the bio-ISRU process generates 44 tons of excess clean oxygen that could be set aside to use for other purposes, such as supporting human colonization.

Three resources native to Mars – carbon dioxide, sunlight, and frozen water – would be used to produce both propellant and liquid oxygen on the red planet. The process would also include transporting two microbes to Mars: cyanobacteria, which would take CO_2 from the Martian atmosphere and use sunlight to create sugars; and an engineered *E. coli* to convert those sugars into a Mars-specific propellant.

"You need a lot less energy for lift-off on Mars, which gave us the flexibility to consider different chemicals that aren't designed for rocket launch on Earth," said **Pamela Peralta-Yahya**, the corresponding author of the study and an associate professor in the School of Chemistry and Biochemistry and the School of Chemical and Biomolecular Engineering, who engineers microbes for the production of chemicals. "We started to consider ways to take advantage of the planet's lower gravity and lack of oxygen to create solutions that aren't relevant for Earth launches."

The multidisciplinary team was led by **Nicholas Kruyer** (Ph.D. ChBE '21), and composed of **Caroline Genzale**, associate professor in Mechanical Engineering; **Wenting Sun**, associate professor in Aerospace Engineering; and **Matthew Realff**, professor in Chemical and Biomoleuclar Engineering. The study was published in a *Nature Communications* paper, "Designing the bioproduction of Martian rocket propellant via a biotechnology-enabled in situ resource utilization strategy." • JASON MADERER

Research supported by NASA Innovative Advanced Concepts (NIAC) Award.


Pamela Peralta-Yahya

Dipping a Toe in Jupiter's Atmospheric 'Oceans' and Polar Cyclones

Photographs from the Juno spacecraft have given oceanographers — including **Annalisa Bracco**, a professor studying ocean and climate dynamics with the School of Earth and Atmospheric Sciences — the raw materials for a new study describing the rich turbulence at Jupiter's poles and the physical forces that drive its large cyclones. The study was published in January in *Nature Physics*.

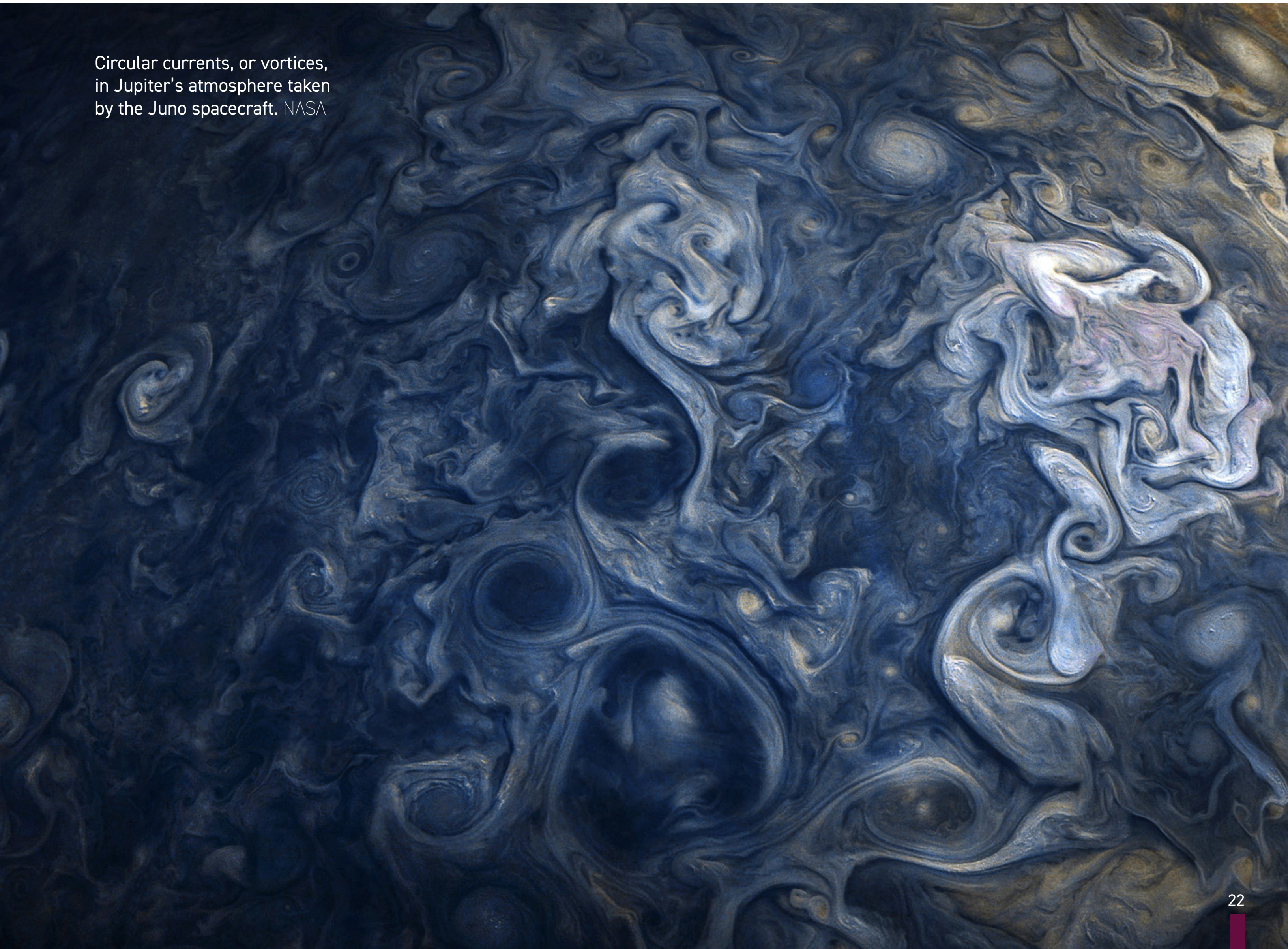
Using an array of these images and principles used in geophysical fluid dynamics, the study's lead author, **Lia Siegelman**, a physical oceanographer and postdoctoral scholar at Scripps Institution of Oceanography at the University of California, San Diego, joined Bracco and their colleagues to provide evidence for a longtime hypothesis that moist convection — when hotter, less dense air rises — drives these cyclones.

"Jupiter's poles were never observed before with this clarity," said Bracco. "We had no idea that there were cyclones organized in structures, with a central one and five or seven around it."

Understanding Jupiter's energy system could also help us understand the physical mechanisms at play on our own planet by highlighting some energy routes that could also exist on Earth. • RENAY SAN MIGUEL

In addition to Siegelman and Bracco, the study's collaborators include scientists from the California Institute of Technology and Italy's main space sciences research organization, Istituto Nazionale di AstroFisica — Istituto di Astrofisica e Planetologia Spaziali.

Research supported by SIO, NASA, NSF, and Agenzia Spaziale Italiana.



Circular currents, or vortices, in Jupiter's atmosphere taken by the Juno spacecraft. NASA

THE EDGE

of climate science, biodiversity, ecosystem resilience, and global change

PHOTO: CODY CLEMENTS

Cody Clements surveys rows of coral "gardens." QUENTIN SCHULL

Underwater Gardens Boost Coral Diversity to Stave Off 'Biodiversity Meltdown'

Symbiotic relationship between Pacific Ocean coral species offers a potential solution to restore climate-damaged reefs

Corals are the foundation species of tropical reefs worldwide, but stresses ranging from overfishing and pollution to warming oceans are killing corals and degrading the critical ecosystem services they provide. Because corals build structures that make living space for many other species, scientists have long known that losses of corals result in losses of other reef species. But the importance of coral species diversity for corals themselves has been less understood.

A new study from two researchers provides both hope and a potentially grim future for damaged coral reefs. In their research paper, "Biodiversity has a positive but saturating effect on imperiled coral reefs," published last October in *Science Advances*, **Cody Clements** and **Mark Hay** found that increasing coral richness by 'outplanting' a diverse group of coral species together improves coral growth and survivorship.

"Corals are the foundation species of these ecosystems — providing habitat and food for numerous other reef species," said Clements, Teasley Postdoctoral Fellow in the School of Biological Sciences. "Negative effects on corals often have cascading impacts on other species that call coral reefs home. If biodiversity is important for coral performance and resilience, then a 'biodiversity meltdown' could exacerbate the decline of reef ecosystems that we're observing worldwide."

Clements and Hay traveled to Mo'orea, French Polynesia, where they planted coral gardens differing

"Negative effects on corals often have cascading impacts on other species that call coral reefs home. If biodiversity is important for coral performance and resilience, then a 'biodiversity meltdown' could exacerbate the decline of reef ecosystems that we're observing worldwide."

Cody Clements, School of Biological Sciences

in coral species diversity to evaluate the relative importance of mutualistic versus competitive interactions among corals as they grew and interacted through time.

"We've done the manipulations, and the corals should be competing with each other, but in fact they do better together than they do on their own," said Hay, Regents' Professor and Teasley Chair in Biological Sciences, and co-director of the Ocean Science and Engineering graduate program at Georgia Tech.

Coral reefs are under threat worldwide. Hay noted that the Caribbean has lost 80 to 90 percent of its coral cover. The Indo-Pacific region has lost half of all its corals over the last 30 years. During the bleaching event of 2015-2016 alone, nearly half of the remaining corals along the Great Barrier Reef bleached and died.

"There are hot spots here and there where coral reefs are still good, but they're small and isolated in general."

In their coral gardens in French Polynesia, Hay and Clements manipulated the diversity of the coral species that they planted on platforms resembling underwater chess tables, to try and see if species richness and density affected coral productivity and survival.

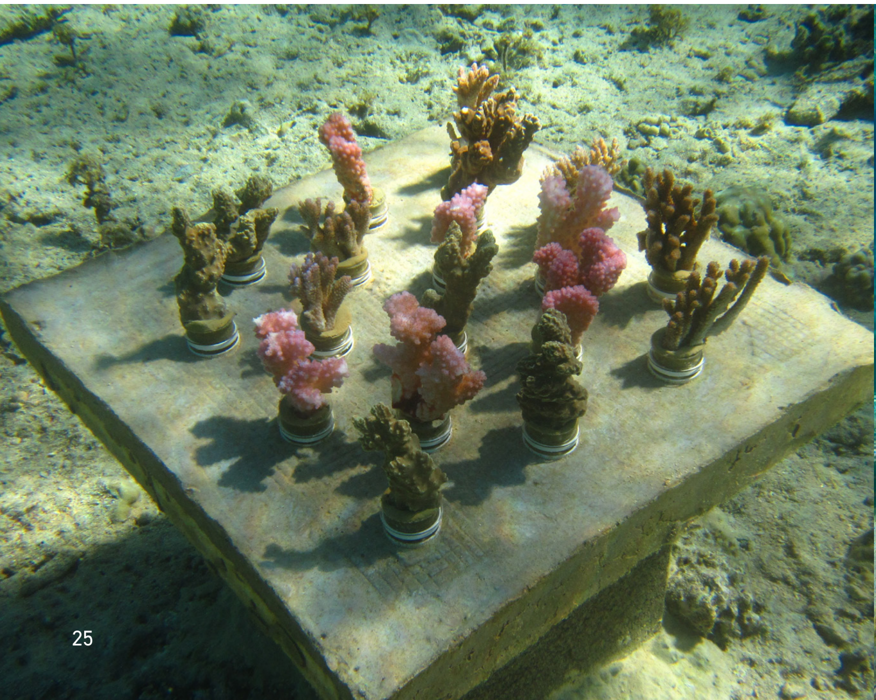
An experimental setup suggested by Clements involving Coke bottles helped the scientists arrange their garden. The end tables "have Coca-Cola bottle caps embedded in the top of them," Hay said. "We can then cut off the necks of Coke bottles, glue corals into the upside-down necks of these things, and then screw them in and out of these plots. This allows us to not only arrange what species we want where, but every couple of months we can unscrew and weigh them so we can get accurate growth rates."

Clements said their research demands more investigation. Why do corals perform better in mixed species communities than single-species communities? Why does this biodiversity effect diminish — rather than continue increasing — at the highest level of coral diversity?

"We need a better mechanistic understanding of how diversity influences these processes to predict how biodiversity loss will impact corals, as well as how we may be able to harness biodiversity's positive influence to protect corals," said Clements. • RENAY SAN MIGUEL

Research supported by the National Science Foundation, the National Geographic Society, the Teasley Endowment to the Georgia Institute of Technology, and the Teasley Gift Fund.

Coral species growing in the underwater reef garden near Mo'orea, French Polynesia. CODY CLEMENTS



Mark Hay Elected to National Academy of Sciences, American Academy of Arts & Sciences

Mark E. Hay has been elected a member of the National Academy of Sciences and the American Academy of Arts & Sciences.

Hay, Regents' Professor and Teasley Chair in Environmental Biology in the School of Biological Sciences, is among 120 members and 30 international members recently elected to the National Academy of Sciences (NAS) in recognition of their distinguished and continuing achievements in original research. Established by an Act of Congress, signed by President Abraham Lincoln in 1863, the NAS is charged with providing independent, objective advice to the nation on matters related to science and technology. Scientists are elected by their peers to membership for outstanding contributions to research.

The American Academy of Arts & Sciences was founded in 1780 by John Adams, John Hancock, and others to honor exceptionally accomplished individuals and convene leaders in advancing the public good. Hay, an experimental marine ecologist known for his work on community and chemical ecology, is being recognized by the organization for decades of world-renowned research in the field. He is among 261 artists, scholars, scientists, and leaders in the public, nonprofit, and private sectors who will be inducted in 2023.

"I am honored to be associated with a group that has shaped not only science and art — but the human experience and culture in general for more than two centuries," said Hay.

"Mark is an international leader in the field of marine chemical ecology," said **Susan Lozier**, dean of the College of Sciences and Betsy Middleton and John Clark Sutherland Chair. "His work has helped build our modern understanding of marine ecosystems and has guided marine conservation efforts across the globe."

Hay founded and co-directed the Center for Aquatic Chemical Ecology, now merged with the Center for Microbial Dynamics and Infection at Georgia Tech. His research has provided key insights into the conservation and restoration of coral reefs, and has challenged scientists' views of ecological and evolutionary processes affecting the establishment and impact of invasive species.

"I am honored to be associated with a group that has shaped not only science and art — but the human experience and culture in general for more than two centuries."

Mark E. Hay, School of Biological Sciences

"Most organisms have neither eyes nor ears and so must use chemical cues to decide whether to attack, mate with, or escape from the organism next to them," Hay said. "Learning and interpreting these chemical cues provides an instruction manual for the critical processes structuring Earth's populations, communities, and ecosystems. This deeper understanding then produces novel approaches for improving conservation, management, and restoration of threatened and collapsed natural systems." • JESS HUNT-RALSTON

Ocean Science & Engineering graduate Minda Monteagudo, who is now an Energy Systems Postdoctoral Scientist at Lawrence Livermore National Laboratory.

Ocean Science & Engineering Celebrates First Graduate

This past school year, the Ocean Sciences and Engineering Ph.D. program at Georgia Tech celebrated its first graduate, **Minda Monteagudo**. The program was established in 2014 as an interdisciplinary study integrating biology, civil engineering, and earth and atmospheric sciences. Monteagudo was approached to join the program due to her interest in climate change and how it affects the ocean.

"It is a home that brings together people who work on ocean science," Monteagudo said. There are many events with students in the program that have made it feel like a home for Monteagudo on campus that extends beyond the classroom, she added, finding close friends during her time in the program while receiving support from her faculty mentors.

"Tech was defined by the people in my department," she said. Now, she is excited to see what future cohorts will accomplish. Next year will be the first full group of students graduating, and many are already writing their dissertations. Monteagudo recently finished hers on fossil shells in ocean sediment. She used chemistry to reconstruct ocean temperatures from the geological past. These findings can be used to bolster current models of future temperature changes by seeing if they match past records.

Her time as a teaching assistant for EAS 2600 (Earth Processes) helped her combine a love of teaching with interacting with undergraduate students.

"Students saw connections from earth and atmospheric sciences to their own majors, so I was able to learn many things from their personal experiences," Monteagudo said.

As a graduate student, she also joined a task force for racial equality with 12 other students, blazing new trails and helping shape a better future for all students.

• CONNOR WHITE

Creative Cutting-Edge Coral Scientist: Kristen Marhaver

Kristen Marhaver (BIO '04) speaks for the corals.

The scuba diver, underwater photographer, and world-renowned expert in coral breeding has racked up more than 2.3 million views of her engaging TED talks, in which she shares her ground-breaking innovations and heartfelt passion for preserving these little-understood and greatly undervalued marine creatures.

"Corals are so distant from us evolutionarily, so foreign and alien, that you really have to be creative in thinking about what their life is like and what they need to survive," she said.

In her research lab at CARMABI (Caribbean Research and Management of Biodiversity) on the island of Curaçao, Marhaver and her team have made great strides in aiding coral survival by inventing methods for coral breeding, baby coral propagation, and coral gene banking.

"It's like running an IVF clinic, a neonatal intensive care unit, and a daycare all at once for an endangered species," she said.

Through hundreds of night dives, she and her colleagues pinpointed the timing for the spawning of numerous Caribbean coral species. Their spawning charts are now used by dozens of research teams to collect and preserve coral sperm and eggs. Marhaver was also the first person in the world to raise baby pillar corals, a nearly extinct Caribbean coral species. Juvenile corals supercharge reefs; they spawn more prolifically and adapt more readily to changing environments.

"Corals are so distant from us evolutionarily, so foreign and alien, that you really have to be creative in thinking about what their life is like and what they need to survive."

Kristen Marhaver (BIO '04)

"Raising young corals today boosts the reproduction on future coral reefs for centuries," she said.

Her lab's Genome Resource Bank takes an even longer view. Its 500 billion (and counting) cryopreserved coral sperm can survive indefinitely, serving as the ocean equivalent of a seed bank that endures whatever disease outbreaks or thermal events arise.

She is always eager to speak for the corals: about their critical role in shoreline protection, their value to land economies, their tremendous potential as a source of future medications and, well, just how cool they are. "There's lots of reasons to keep corals around, for sure," she said.

She's grateful and thrilled to be part of the global community devoted to that very cause. "Collaborators, awesome students, and mentors have been so critical in all the progress we've made," she says. Her father, Carl Marhaver, was her first mentor, who first took her scuba diving at age 15. "He was in charge of all the logistics, and I was in charge of all the small animal encounters," she said with a laugh.

She credits Tech for providing her with the invaluable combination of lab research skills and field ecology experience that she draws on daily. As a first-year student, she pleaded her way into the lab of **Terry Snell**. He first let her observe his work on coral stress genomics before promoting her through the ranks as a lab assistant — and helping set her course toward her celebrated career.

In gratitude, Marhaver now sponsors a first-year biology researcher each year at Tech through the FastTrack Research Program. "That's how it all began for me," she said. "It means a ton to be able to pay it forward to support someone who is in my shoes 20 years later."

• KRISTIN BAIRD RATTINI

Kristen Marhaver (BIO '04). GEORGIA TECH ALUMNI MAGAZINE

Seawater Seep May Be Speeding Glacier Melt, Sea Level Rise

Alexander Robel has led a study projecting that warm seawater seeping under certain glaciers could eventually lead to future sea level rise that's double that of existing estimates

Alexander Robel holds ice used in glacial melt research.

The melting of ice sheets at the points where they float on and along the world's oceans is a major climate culprit when it comes to sea level rise. But less is understood about the extent of melting that is due to warm, salty seawater that seeps underneath "grounded" portions of ice sheets along land, as well as what happens when that mix intrudes deep under glacier interiors.

A study published in *The Cryosphere* led by **Alexander Robel**, an assistant professor in the School of Earth and Atmospheric Sciences, may provide some clarity. Robel, who leads the Ice & Climate Group at Georgia Tech, and his team of researchers have developed a theory that finds glacial melt may be happening faster out of sight than previously estimated.

"The paper shows warm seawater can intrude underneath glaciers, and if it causes melting at the glacier bottom, can cause predictions of future sea level rise to be up to two times higher than current estimates," Robel said. "Put another way, our research showed that the grounding line (where glacial ice meets water) is not the sort of impenetrable barrier between the glacier and the ocean that has previously been assumed."

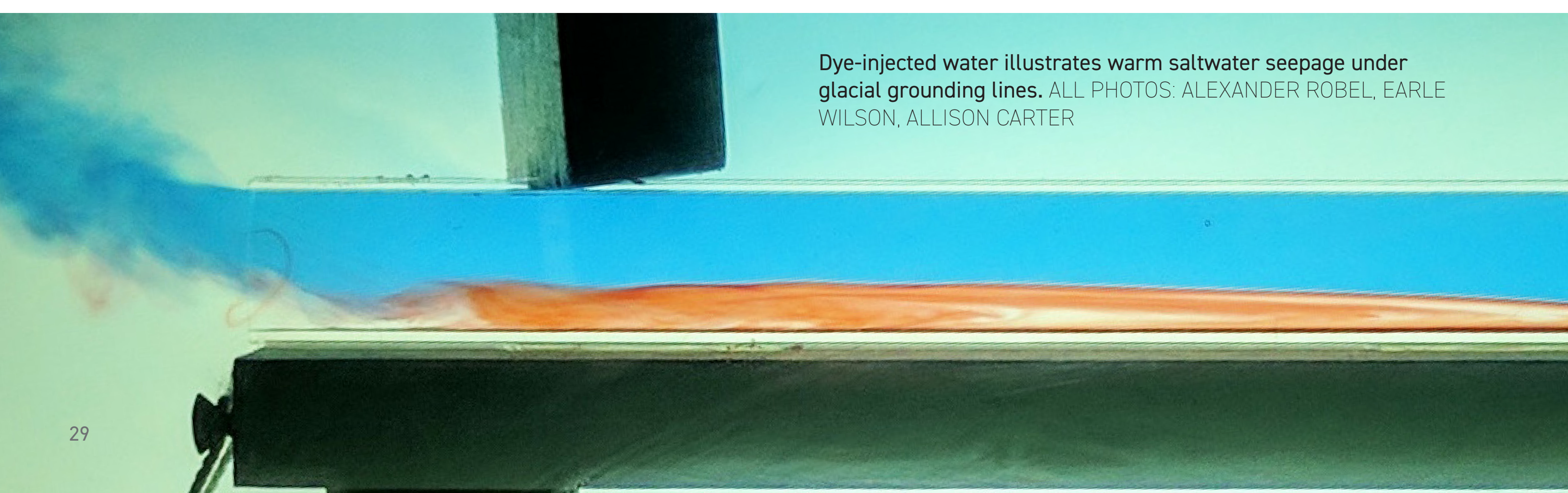
Using predictions based on mathematical and computational models, the study shows that seawater intrusion over flat or reverse-sloping impermeable beds may feasibly occur up to tens of kilometers upstream of a glacier's end or grounding line.

Fresh meltwater stays close to the temperature of the ice it came from, but salty seawater that intrudes under glaciers may also bring heat from the ocean, which researchers say has the potential to cause much higher rates of melting at the glacier bottom.

Robel's co-authors for the study are **Earle Wilson**, assistant professor at Stanford University; and **Helene Seroussi**, an associate professor at Dartmouth College.

The new study uses basic mathematical theory of fluid flow and large computer models run on the Partnership for an Advanced Computing Environment (PACE) high performance computing cluster at Georgia Tech to make its predictions, and builds on a 2020 study led by Wilson which showed how such intrusions could occur through confined channels using experiments and modeling.

"Past measurement from field expeditions and satellites have hinted that seawater may intrude subglacial meltwater channels," Wilson noted, "much like how the ocean may flow upstream and mix with river water in a typical estuary. Our study shows subglacial estuaries are



Dye-injected water illustrates warm saltwater seepage under glacial grounding lines. ALL PHOTOS: ALEXANDER ROBEL, EARLE WILSON, ALLISON CARTER not just possible but likely over a wide range of realistic scenarios, and their existence has profound implications for future sea level rise."

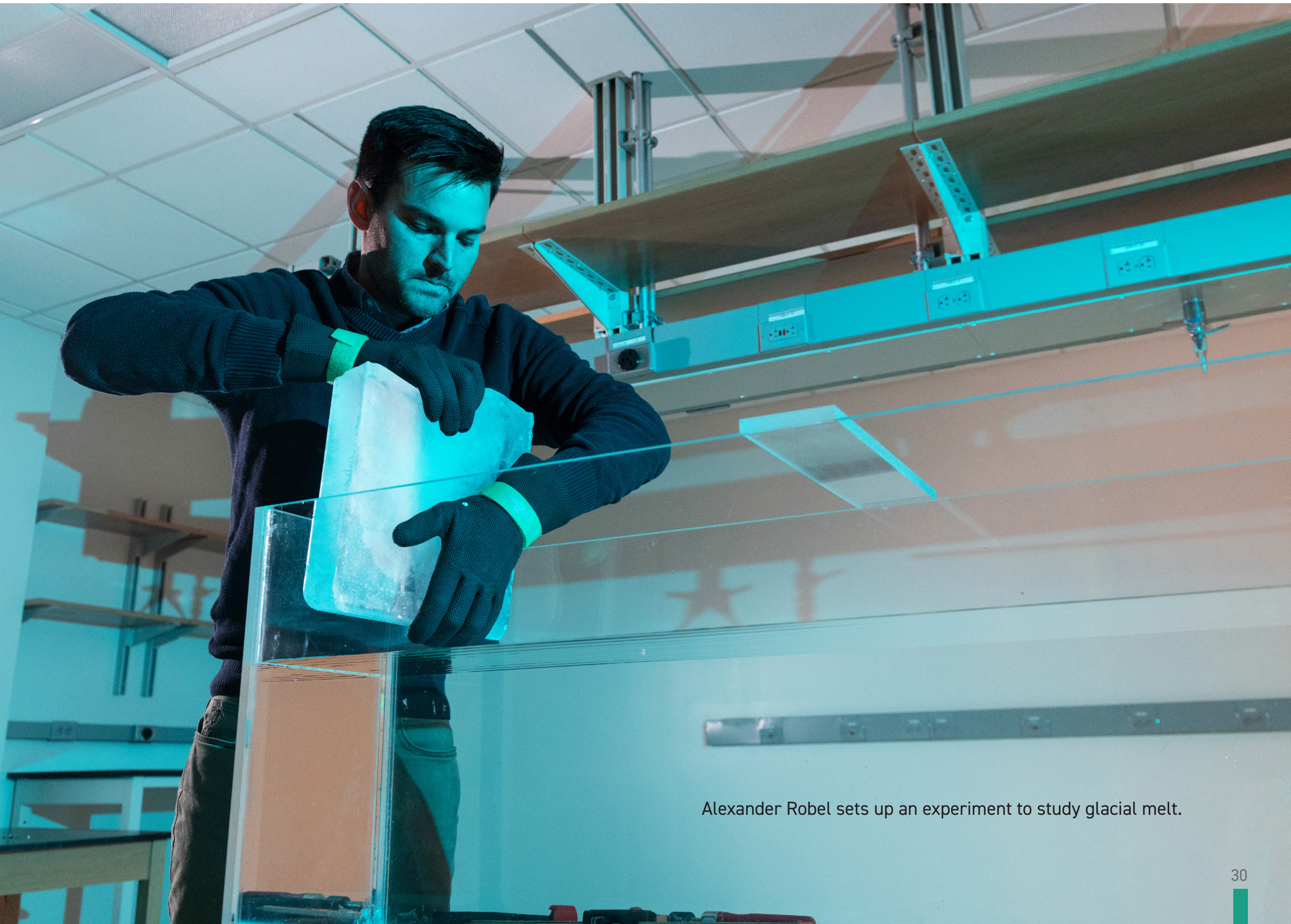
"Simulations show that even just a few hundred meters of basal melt caused by seawater intrusion upstream of marine ice sheet grounding lines can cause projections of marine ice sheet volume loss to be 10-50 percent higher," Robel explained. "Kilometers of intrusion-induced basal melt can cause projected ice sheet volume loss to more than double over the next century."

Robel adds that these results suggest that further observational, experimental, and numerical investigations are needed to determine the conditions under which seawater intrusion occurs — and whether it will indeed drive rapid marine ice sheet retreat and sea level rise in the future. The research team will start to look at measurements from past field expeditions to confirm if their theory is true, and are working to secure funding in the next year to go to Antarctica and look for such intrusion in a targeted expedition.

"Overall, this contributes to an important body of current work that tries to estimate how fast ice sheets melt in a changing climate and what physical processes are relevant in driving these rapid changes."

Alexander Robel, School of Earth and Atmospheric Sciences

"Overall, this contributes to an important body of current work that tries to estimate how fast ice sheets melt in a changing climate," Robel added, "and what physical processes are relevant in driving these rapid changes."
• RENAY SAN MIGUEL



Alexander Robel sets up an experiment to study glacial melt.

Meltwater lake on the Sørsdal Glacier, East Antarctica. DAVE LOMAS

Warmer Summers and Meltwater Lakes are Threatening the Fringes of the World's Largest Ice Sheet

An unprecedented study looking at surface meltwater lakes around the East Antarctic Ice Sheet across a seven-year period has found that the area and volume of these lakes is highly variable year-to-year — and offers new insights into the potential impact of recent climatic change on Antarctica.

The research used more than 2,000 satellite images from around the edge of the East Antarctic Ice Sheet to determine the size and volume of lakes on the ice surface. These supraglacial lakes were tracked between 2014 and 2020.

The study, led by Durham University (UK) and published in *Nature Communications* with co-authors from Newcastle and Lancaster universities and Georgia Tech, shows that lake volume varied year-to-year by as much as 200 percent on individual ice shelves (floating extensions of the main Antarctic ice sheet), and by around 72 percent overall.

Lakes were also found to be deeper and larger in warmer melt seasons and formed on some potentially vulnerable ice shelves. It's the first time meltwater lakes have been studied over consecutive melt seasons across the whole ice sheet, enabling the controls on their development to be explored. The work provides vital insight into why and where lakes grow and will help experts understand which ice shelves may be most at risk of breaking up as a consequence of surface melting.

"This work shows that year-to-year variability of supraglacial lakes is important on the East-Antarctic ice shelves. It demonstrates that we need to further improve our models to represent the critical factors leading to such spatio-temporal variability," said co-author **Vincent Verjans**, a postdoctoral fellow in the School of Earth and Atmospheric Sciences at Georgia Tech and member of the Institute's Ice & Climate Group.

"We knew that supraglacial lakes were more extensive than previously thought around the East-Antarctic Ice Sheet, but until now only had snapshots of these in some years," said **Jennifer Arthur**, principal investigator and Ph.D. student in the Department of Geography, Durham University. "Our study reveals these lakes change in scale far more than we originally suspected. We were surprised at how much lakes can change year-to-year between ice shelves. We explored the potential reasons for this and found that warmer summer air temperatures in Antarctica correlated with more extensive lakes."

In addition to helping experts understand supraglacial lake formation and climatic impacts, the team's research seeks to predict which ice shelves may be most at risk of collapse.

Understanding the climatic conditions controlling meltwater lake variability will also improve the accuracy of regional climate models used to replicate observations and predict future ice sheet change in Antarctica. • JENNIFER ARTHUR

Work on this study was funded through a UKRI Natural Environment Research Council doctoral studentship and individual author grants from the Natural Environment Research Council.

Susan Lozier Appointed to Climate Security Roundtable

At the direction of Congress, the National Academies of Sciences, Engineering, and Medicine have established a new Climate Security Roundtable to convene experts across academia, the private sector, and civil society.

College of Sciences Dean **Susan Lozier** will serve a three-year term on the inaugural committee, which seeks to aid the U.S. Climate Security Advisory Council in anticipating, preparing, and ultimately preventing climate security crises from escalating into national security challenges and threats.

A physical oceanographer whose research focuses on the ocean's role in climate variability and climate change, Dean Lozier is President of the American Geophysical Union — representing 62,000 members across 144 countries — as well as a professor in Earth and Atmospheric Sciences and Betsy Middleton and John Clark Sutherland Chair at Georgia Tech.

This year, Lozier also received the highest honor that the American Meteorological Society awards to an oceanographer for her "theoretical, observational, modeling contributions, and leadership in significantly improving our understanding of Atlantic Ocean circulation" through ocean science and engineering and as international project lead for the National Science Foundation's Overturning in the Subpolar North Atlantic Program — OSNAP, for short.

• JESS HUNT-RALSTON

PHOTO: ROB FELT

Georgia Grown

Salt marsh grass on Georgia's coast gets nutrients for growth from helpful bacteria in its roots

Salt marshes cover much of the state of Georgia's coast and perform key "ecosystem services" for people. They clean the water, protect coastlines against storm surges, and provide a habitat for fish and shellfish. A new study finds that a species of grass that dominates those marshes has bacteria in its roots and surrounding soil that affects productivity by providing nutrients, highlighting the importance of soil microorganisms in the entire ecosystem.

The study, "The core root microbiome of *Spartina alterniflora* is predominated by sulfur-oxidizing and sulfate-reducing bacteria in Georgia saltmarshes, USA" is published in *Microbiome*. The research team includes Georgia Tech Ph.D. students **Jose Rolando** (the study's lead author) and **Tianze Song**; **Max Kolton**, a former postdoctoral researcher, now senior lecturer and principal investigator with Ben-Gurion University of the Negev in Beer Sheva, Israel; and corresponding author **Joel Kostka**, professor and associate chair for Research in the School of Biological Sciences with a joint appointment in the School of Earth and Atmospheric Sciences, who is also a member of Georgia Tech's Center for Microbial Dynamics and Infection.

The study shows that diverse and abundant microbes associated with spartina cordgrass help mineralize sediment organic matter and release bioavailable nutrients to the plant, suggesting that the microbes help support plant productivity.

The work could assist efforts to restore salt marshes that will help to strengthen the coastline to be more resilient in the face of sea level rise and climate change.

Kostka said about 40 percent of salt marshes have disappeared in the U.S. over the past 100 years. "So coastal ecosystem restoration has become a huge field, with an important goal to manage or restore marshes so that they continue to provide critical ecosystem services to people," he explained.

Sulfur in the roots

The study was conducted at salt marshes near Sapelo and Skidaway Islands on the Georgia coast in 2018 and 2019. There, ocean water washes over the salt marsh grasses, and that water is rich in sulfate. “Sulfide is a phytotoxin or plant toxin,” Kostka said. “A lot of sulfide will kill plants or at least stress them out, but when you add just a little bit (to *Spartina alterniflora*), it fuels microbial factories in the plant roots.”

Kostka’s team found that *Spartina alterniflora* has concentrated sulfur bacteria in its roots, and those bacteria are in two categories: sulfur oxidizers, which use sulfide as an energy source — “then you have sulfate reducers which breathe or respire sulfate from seawater, producing sulfide.”

In this microbial cell factory, bacteria are using sulfide as an energy source to fix nitrogen — and possibly carbon — which is then passed to the grasses. Nitrogen fixation happens when a microbe takes nitrogen gas from air or water and makes usable ammonium out of it. In nature, soil microbes primarily perform this process — occasionally lightning in the atmosphere can also spark it.

The research team at the University of Georgia Marine Institute. Clockwise from left: Researchers Joel Kostka, Jose Rolando, Tianze Song, Max Kolton.

The study’s findings suggest that fixation is happening via chemoautotrophy (using chemical reactions for energy) by bacteria living inside the plant roots.

“The next chapter of this story is to learn how the plant and bacteria exchange nitrogen and the environmental controls of that exchange,” Kostka said. “We also know these bacteria can fix carbon, and could potentially be passing carbon to the plant. The plant may have a cell factory that’s making biomass from chemical energy rather than photosynthesis.”

The saltwater marshes that Kostka’s team studies have also been termed “blue carbon” sinks because they act to mitigate climate change by sequestering large amounts of carbon from the atmosphere on a global scale. “Salt marshes or coastal marshes are not only critical as habitat for fish and shellfish that we like to eat — along with other vegetated coastal ecosystems — they store as much or more carbon as the remainder of the seafloor,” Kostka said.

A triumph for omics, and what’s next

Kostka credits ‘omics’, technologies which allow for the study of microbes in the environment without cultivation, for advances in uncovering microbiomes — all the microorganisms in a specific environment. Metagenomics and metatranscriptomics, the sequencing of all genes or expressed genes in the environment, allow scientists to chart the potential for microbes to carry out important ecosystem functions like nitrogen fixation. This is critical since very few microbes out of the large diversity that can be grown in the lab, Kostka explained.

“The work is another example of how we are uncovering plant microbiomes — the microbes that live inside or on the tissues of environmentally relevant plants that help the plants to grow better,” Kostka added. “If we can add microbes to the roots when we plant them, and therefore increase the survival of those plants, we can improve restoration efforts.” • RENAY SAN MIGUEL

Left: *Spartina alterniflora*, the dominant plant in salt marshes on the Atlantic and Gulf coasts of the U.S., in the Dean Creek marsh. Right: School of Biological Sciences researchers set up a study site near Dean Creek on Sapelo Island.

Getting to the Root of Plant-Soil Interactions

Optical instrument to give clearest 3D images yet of rhizosphere

An interdisciplinary team of researchers from Georgia Tech has received a $2 million federal grant to create tools that will provide the clearest three-dimensional images yet of the chemical and biomolecular interactions between plants and the soil in which they grow.

At just a few inches underground, the rhizosphere — the thin strip of earth that includes the soil-root interface — has so far been difficult to visualize on site. If scientists can build instruments that capture in real-time clearer images of the physical associations of microbes attached to roots, along with the oxygen-carbon-nitrogen chemical exchanges they mediate, it could help mitigate the effects of climate change and lead to the development of more sustainable fuels and fertilizers.

"From a microbiological perspective, we have catalogued what microbes are in the root zone and how abundant they are," said **Joel Kostka**, professor in Biological Sciences and Earth and Atmospheric Sciences. "But there's been very little work to understand their dynamics under real soil conditions."

Kostka joins **Marcus Cicerone**, professor in the School of Chemistry and Biochemistry and principal investigator for the new grant from the U.S. Department of Energy's Office of Biological and Environmental Research. The research team also includes **Francisco Robles**, assistant professor in the Wallace H. Coulter Department of Biomedical Engineering; and **Lily Cheung**, assistant professor in the School of Chemical and Biomolecular Engineering.

Together, the researchers plan to produce a new optical instrument that will provide 3D images of dynamic metabolic processes with chemical specificity. The instrument will be built with an eye toward simplicity so that it can be easily leveraged by Department of Energy (DOE) Bioenergy Research Centers and field sites.

A 'hotspot for microbes' in 3D

Kostka says that the rhizosphere is "a hotspot for microbes."

"It's often where the plant is communicating with the outside world," he explained. "Our goal is to develop an instrument that [the DOE] can use to better understand those interactions between plants and microbes and how those can be tweaked, say, to optimize plant production, crop production, biofuels, and biomass production."

Cicerone and Robles will build instrumentation that will focus light into the soil and that is "exquisitely sensitive to the minuscule amount of light that only scatters when it reaches its target." Evaluating that light will help scientists learn even more about the chemical processes in the rhizosphere.

"This is a three-year funded project, and we hope at the end of the three years to have an experimental system, where we can do something that nobody else can do," Cicerone added. "And that is that we can follow the biochemistry under the soil, *in situ*, in real time, to clearly see what's going on there and find out what the microbes really are doing in natural conditions. At that point, we can start manipulating the biology, start doing the experiments that the DOE is primarily interested in." • RENAY SAN MIGUEL

The rhizosphere is the thin strip of earth that includes the soil-root interface. JOEL KOSTKA

An aerial view of the Georgia Coast. GEORGIA TECH

With Recent Funding, Sea Level Sensor Project in Savannah Moves into New Phase

The rising sea levels along Georgia's Savannah coast and an uptick in more severe storms during hurricane season are bellwethers to looming ecological challenges stemming from climate change.

Ongoing research to study sea level rise led by Georgia Tech researchers, a coalition of universities, Savannah and Chatham County government leaders, and local community groups is creating what could be a national model for coastal regions across the country facing similar challenges.

Launched in 2018 with a Georgia Smart Communities Challenge Grant, the data collected from the sea level sensors is used to inform city and county planners and emergency responders on resource deployment following major weather events.

Now in its fourth year, the sea level sensor project is slated to receive $5 million from Congress to launch the Coastal Equity and Resilience Hub. It is secured by U.S. Sens. **Jon Ossoff** and **Raphael Warnock**, and U.S. Rep. **Earl L. "Buddy" Carter** to expand the network of sensors — currently 50 are deployed off Chatham County's coast — to blanket Georgia's 11-county coastal region.

"It's going to translate into saved lives and saved infrastructure."

Kim Cobb, Director, Institute at Brown for Environment and Society

"With this new funding, we are recognizing a new phase of our project which has evolved," said **Kim Cobb**, former professor in the School of Earth and Atmospheric Sciences, recently appointed as director of the Institute at Brown for Environment and Society.

Cobb and **Russell J. Clark**, senior research scientist in the School of Computer Science at Georgia Tech's College of Computing, co-lead the project. **Allen Hyde**, assistant professor in the School of History and Sociology in Georgia Tech's Ivan Allen College of Liberal Arts, leads a National Science Foundation project focused on disaster resilience as part of the effort.

The new funding will support expansion of building out more hyperlocal flood forecasting models, resilience planning tools for underserved communities, and further development of a K-12 education curriculum, paid internships, and other workforce development programs.

Georgia Tech and its partners in the Coastal Equity and Resilience Hub — which includes Savannah State University, the University of Georgia, and the University of South Carolina — are using these low-cost sensors to gain real-time data that over time will help inform the policies on infrastructure design and retrofitting, Cobb said. They will also further expand first responders' and emergency planners' ability to forecast extreme rainfall and storm surge events on a neighborhood-by-neighborhood specific basis.

"It's going to translate into saved lives and saved infrastructure," Cobb said.

A national model

Hub researchers say the data being collected from the sensors and additional information gleaned from the sensor expansion have immediate applications in terms of flood disasters and hurricanes. Those findings could also help frame the national dialogue and help inform policy as leaders in Washington shape it to tackle rising sea levels and climate change.

The award is part of a broader federal push, including a $12 billion funding package, to help Georgia and other states along the Eastern Seaboard, as well as the West

"When you're dealing with or managing or mitigating an issue that's affecting society, it's got to involve research and dialogue with the community. This project is allowing us to recognize that the community themselves are the subject matter experts."

Dawud Shabaka, Harambee House, Savannah

and Gulf coasts, develop resiliency and flooding plans and protocols to mitigate damage from future floods.

Cobb said this new funding specifically allows the Hub to further efforts in its research while expanding education and workforce development — particularly in underserved minority communities — as components of the broader strategy.

"Our project started out anchored on the sensors and trying to provide real-time data to emergency planners and emergency responders, but it's no longer just a small team of people who are interested in sensors, or physical scientists, engineers, and researchers on the science and technology side," she said, explaining the research team of some 30 people also includes policy and planning experts, along with community advocates.

"We're trying to think about solutions in the context of history, geography — the history of people, cultures, and economies down on the coast," Cobb said. "There's no waving a magic wand and making this all right, especially for the most vulnerable communities."

Community voice

In broad terms, the project touches flooding, infrastructure, property, and pollution. But this newer phase brings in aspects that go beyond scientific modeling of risk, said **Dean Hardy**, an assistant professor in the University of South Carolina's Department of Geography.

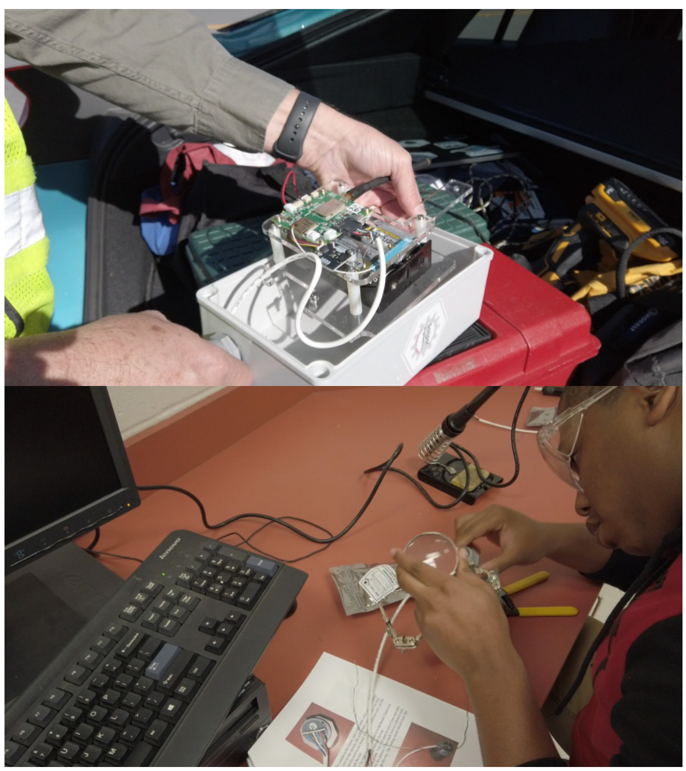
It's what he calls the "human dimension" phase.

"There are disaster plans, there's resiliency plans, and there's community-level thinking. But what we need is systemic change," said Hardy, whose research expertise is in geography and integrative conservation, which marries preservation and social and community goals with public policy.

"So, what I hope partially comes out of this is not just a bunch of scientific publications or better scientific understanding of these issues, but capacity-building with community organizations that leads to the capacity for self-determination."

That acknowledgment is important to marginalized communities, said **Dawud Shabaka**, managing director of Harambee House, in Savannah. The organization, which is involved in the sensor project, promotes and advocates for civic engagement and environmental justice from the coastal city's Black residents and youth.

Shabaka noted that the engagement component, particularly local high school and middle school students working on the sensors and coding, has allowed the participants to see themselves not only as budding scientists, but as future community leaders.



Top: A close-up view of the sensor being used to monitor sea levels off the Georgia Coast. Bottom: Students from Savannah's Herschel V. Jenkins High School get hands-on experience in studying the sea level sensors, data analysis, and interpreting the results.

"When you're dealing with or managing or mitigating an issue that's affecting society, it's got to involve research and dialogue with the community. This project is allowing us to recognize that the community themselves are the subject matter experts," said Shabaka. "Having the students involved at an early age benefits society as a whole and lets them know that the work they're doing is having a much wider impact. This is the type of community engagement that needs to happen to make people feel like they're worthwhile."
• PÉRALTE C. PAUL

Temperate Glimpse Into a Warming World

For the past six years, multidisciplinary researchers from across the world have been probing northern Minnesota peat bogs in an unprecedented, long-range study of climate change, supported by the U.S. Department of Energy. They set out to answer complex questions, including one big one – will future warming somehow release 10,000 years of accumulated carbon from peatlands that store a large portion of Earth's terrestrial carbon?

So the Oak Ridge National Laboratory (ORNL) partnered with the USDA Forest Service to develop a one-of-its-kind field lab in the Marcel Experimental Forest, where below and above ground heating elements are gradually warming the bog in greenhouse-like enclosures big enough to include trees. The enclosures are roofless so that rain and snow can get in.

It's called the SPRUCE (Spruce and Peatland Responses Under Changing Environments) experiment, and it was designed as a window into what would happen to peat bogs in a warmer world. A recent study, headed by Georgia Tech microbiologist **Joel Kostka**, and published June 14 in the journal *Proceedings of the National Academy of Sciences* (PNAS), provides a sobering outlook.

"The real concern and one of the major conclusions of this paper is that the ecosystem we're studying is becoming more methanogenic," said Kostka, professor and associate chair of Research in the School of Biological Sciences, who holds a joint appointment in the School of Earth and Atmospheric Sciences. "In other words, the warmed bog is enhancing the rate of methane production faster than that for carbon dioxide. This is what we think is going to happen in a warming world, based on our results."

Testy little process

Methanogens are microbes that produce methane, a harmful greenhouse gas that traps up to 30 times more heat than carbon dioxide. Warming the peatland, the researchers found, basically creates a methane production line.

"This occurs because the plant community changes in response to warmer temperatures – mosses decrease and vascular plants increase," said the paper's lead author, **Rachel Wilson**, a researcher with Florida State University's Department of Earth, Ocean, and Atmospheric Science, where she works in the lab of Professor **Jeff Chanton**, co-author and co-principal investigator of the study.

While peatlands comprise just three percent of the Earth's landmass, they store about one-third of the planet's soil carbon. The thinking goes, as global temperatures rise, microbes could break into the carbon bank and the resulting decomposition of the ancient, combustible plant biomass would lead to increased levels of carbon dioxide and methane being released into the atmosphere, accelerating climate change.

A SPRUCE enclosure. GEORGIA TECH

"Methane is a stronger greenhouse gas than carbon dioxide," said Wilson. "Warming the climate stimulates methane production, which will contribute to more warming in a positive feedback loop."

It's a scenario that Chanton called "a critical ecosystem shift. Peat soils that have been stable for thousands of years are giving up the ghost, so to speak. It's a testy little process."

Delayed response

That unpleasant outcome is being delayed somewhat by the extreme conditions found in many peat bogs around the world, including at the SPRUCE experiment site.

"Although most peatlands are in northern regions undergoing some of the most rapid warming on the planet, we're talking about generally cold, acidic soils where there's no oxygen," Kostka noted. "Methanogens grow really slowly under these extreme conditions. We do see their activity increasing with warming, but they're not yet growing that fast."

He has a good idea of what could happen, though. Several years ago, Kostka took soil samples from the Minnesota site and tested them in his lab at Georgia Tech, exaggerating the temperature to a much greater degree than would be possible in a large-scale experiment like SPRUCE.

Raising the temperature by 20 degrees Celsius, about twice the temperature range used in the field experiment, "we saw huge increases in methane and large changes in the microbes that break down soil carbon into greenhouse gases," he said.

An aerial view of the SPRUCE study. OAK RIDGE NATIONAL LABORATORY, U.S. DEPARTMENT OF ENERGY

Next chapter

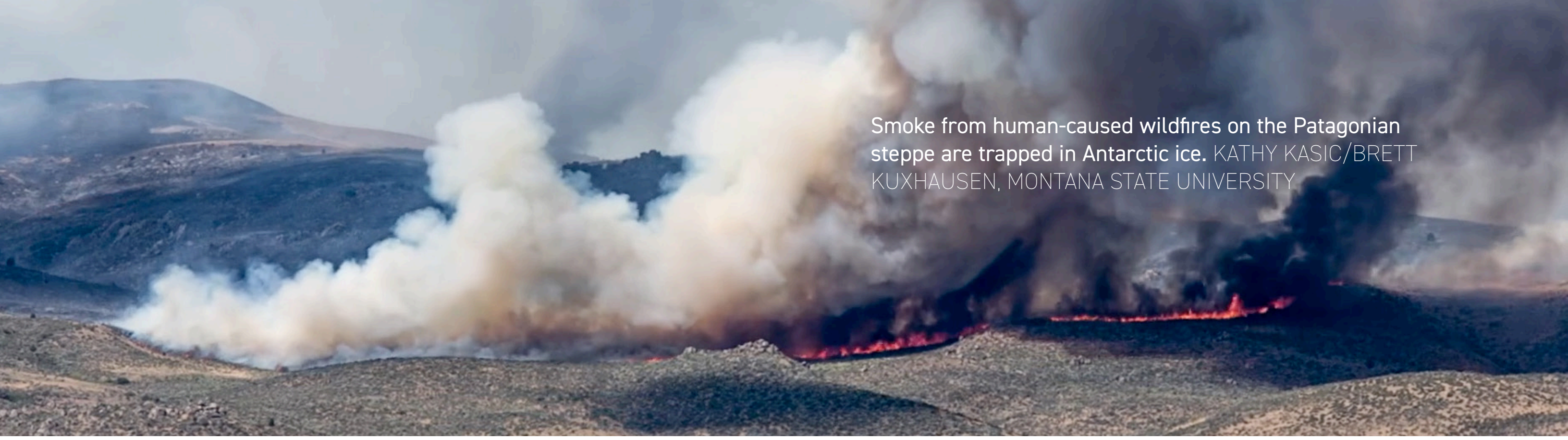
The SPRUCE site experiment involves two kinds of treatment, warming and elevated carbon dioxide. The warming treatment started in 2014. All of the data sets for the *PNAS* paper are from 2016. The elevated carbon dioxide treatment began in the final days of data collection, so it wasn't particularly relevant for this study. "Going forward, we're thinking the effects of elevated carbon dioxide will be one potential future story to tell," Kostka said. "This is a long-term experiment and many of these large scale climate change field experiments do not observe substantial changes to microbial communities until 10 years after they start."

Ultimately, SPRUCE experimental activity is designed and intended to develop a quantitative mechanistic understanding of carbon cycling processes, according to **Paul Hanson**, the Oak Ridge National Laboratory scientist leading the long-range project as principal investigator.

"SPRUCE provides experimental insights for a broad range of plausible future warming conditions for an established peatland ecosystem, combined with or without elevated carbon dioxide," Hanson said.

So far, the evidence is pointing to a bleak possibility: Warming enhances the production of carbon substrates from plants, stimulating microbial activity and greenhouse gas production, possibly leading to amplified climate-peatland feedbacks. Think, gasoline on a fire.

"We are just beginning to see major changes in the microbes and plants at the SPRUCE peatland," he added. Although the first few years of the experiment indicate that a lot more methane will be released to the atmosphere, we will be looking to see if these changes are sustained over the long term." • JERRY GRILLO



Smoke from human-caused wildfires on the Patagonian steppe are trapped in Antarctic ice. KATHY KASIC/BRETT KUXHAUSEN, MONTANA STATE UNIVERSITY

Fiery Past Sheds New Light on the Future of Global Climate Change

Researchers use ice core samples to reveal significant smoke aerosols in pre-industrial Southern Hemisphere

Centuries-old smoke particles preserved in the ice reveal a fiery past in the Southern Hemisphere and shed new light on the future impacts of global climate change, according to new research published in *Science Advances*.

“Up ‘til now, the magnitude of past fire activity, and thus the amount of smoke in the pre-industrial atmosphere, has not been well characterized,” said **Pengfei Liu,** assistant professor in the School of Earth and Atmospheric Sciences at Georgia Tech, and lead author of the study. Liu, who received his Ph.D. in Environmental Sciences from Harvard University in 2017, is a former graduate student and postdoctoral fellow at the Harvard John A. Paulson School of Engineering and Applied Sciences (SEAS). “These results have importance for understanding the evolution of climate change from the 1750s until today, and for predicting future climate.”

One of the biggest uncertainties when it comes to predicting the future impacts of climate change is how fast surface temperatures will rise in response to increases in greenhouse gases. Predicting these temperatures is complicated since it involves the calculation of competing warming and cooling effects in the atmosphere. Greenhouse gases trap heat and warm the planet’s surface while aerosol particles in the atmosphere from volcanoes, fires, and other combustion cool the planet by blocking sunlight or seeding cloud cover. Understanding how sensitive surface temperature is to each of these effects and how they interact is critical to predicting the future impact of climate change.

Looking for clues of smoke aerosols

To model smoke in the pre-industrial Southern Hemisphere, the research team looked to Antarctica, where the ice trapped smoke particles emitted from fires in Australia, Africa, and South America. Ice core scientists and co-authors of the study, **Joseph McConnell** and **Nathan Chellman** from the Desert Research Institute in Nevada, measured soot, a key component of smoke, deposited in an array of 14 ice cores from across the continent — many provided by international collaborators.

“Soot deposited in glacier ice directly reflects past atmospheric concentrations so well-dated ice cores provide the most reliable long-term records,” said McConnell.

What they found was unexpected. “While most studies have assumed less fire took place in the preindustrial era, the ice cores revealed a much fierier past, at least in the Southern Hemisphere,” said **Loretta Mickley**, senior research fellow in Chemistry-Climate Interactions at SEAS and senior author of the paper.

To account for these levels of smoke, the researchers ran computer simulations that account for both wildfires and the burning practices of indigenous people, which suggested that the atmosphere of the Southern Hemisphere could have been very smoky in the century before the Industrial Revolution. “Soot concentrations were up to four times greater than previous studies suggested. Most of this was caused by widespread and regular burning practiced by indigenous peoples in the pre-colonial period,” said **Jed Kaplan**, associate professor at the University of Hong Kong and a co-author of the study.

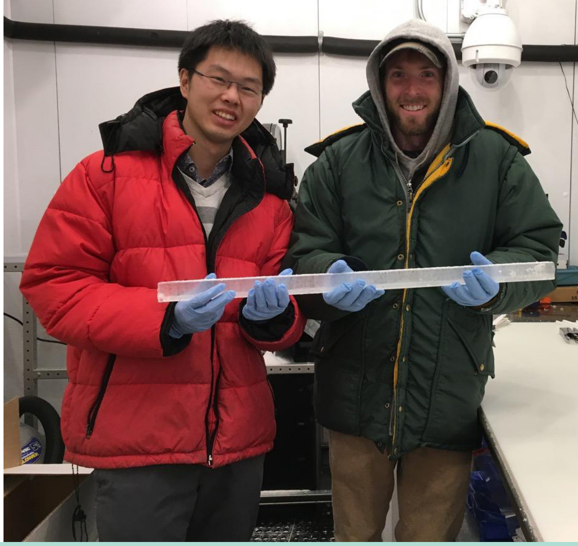
This result agrees with the ice core records that also show that soot was abundant before the start of the industrial era and has remained relatively constant through the 20th century. The modeling suggests that as land use changes decreased fire activity, emissions from industry increased.

What does this finding mean for future surface temperatures?

"Climate scientists have known that the most recent generation of climate models have been overestimating surface temperature sensitivity to greenhouse gasses, but we haven't known why or by how much," said Liu. "This research offers a possible explanation."

"Clearly the world is warming, but the key question is how fast will it warm as greenhouse gas emissions continue to rise. This research allows us to refine our predictions moving forward," said Mickley. • LEAH BURROWS

This research was supported by the National Science Foundation.



Pengfei Liu (left) and Nathan Chellman with an ice core sample. PENGFEI LIU

The Challenge of Predicting Rainfall in a Changing Climate

Jie He, assistant professor in the School of Earth and Atmospheric Sciences (EAS), has received an $854,000 National Science Foundation CAREER Award for his project, "Hydrological Sensitivity Across Timescales." The NSF annually presents the awards to early-career scientists "who have the potential to serve as academic role models in research and education and to lead advances in the mission of their department or organization. Activities pursued by early-career faculty should build a firm foundation for a lifetime of leadership in integrating education and research."

"It felt nice to get the award," He said. "Some of the senior faculty members at EAS had been mentoring me and guiding me on proposal writing, so I felt it's somehow a way to show my appreciation. Because it's a five-year grant, I feel very fortunate to be able to lead a project I care about, and to work on it for a sustained period of time."

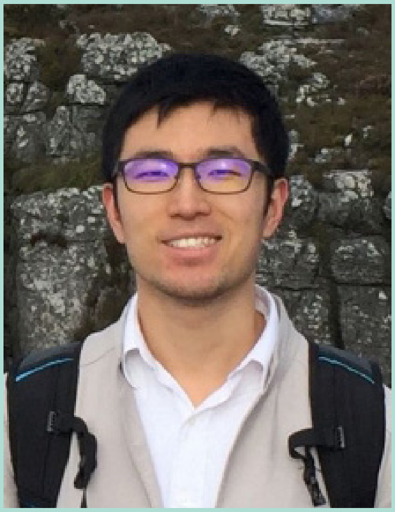
As greenhouse gas concentrations keep rising, the Earth's surface will continue to warm, and the amount of rainfall is expected to change substantially. Predicting how rainfall will change is of great importance for preparing adaptation and mitigation plans, He said.

"Predictions of long-term rainfall changes rely predominantly on simulations of climate models. However, current models disagree on many aspects of rainfall changes, which greatly undermines the usefulness of rainfall predictions," He added. Because observations are generally too short to be used to directly infer long-term rainfall changes, constraining model predictions has been a great challenge.

He has identified several aspects of long-term rainfall changes that are fundamentally tied to how rainfall responds to short-term surface temperature variations. "Based on such relationships, I will evaluate long-term rainfall predictions from climate models by using observed short-term rainfall variations. This work will yield a better understanding of the uncertainty in rainfall predictions and will identify key processes of which observational constraints are available to improve models."

He will then apply this method to a state-of-the-art global climate model, where the identified observational constraints will be used to improve model parameters and ultimately, its prediction of future rainfall changes.

The educational component of He's project involves the teaching and application of climate models at graduate, undergraduate, and high school levels. Specifically, He will create a hands-on climate modeling course for graduate students in climate science, design a climate science and modeling module that can be incorporated into high school science curriculum, and train undergraduate students to conduct and analyze climate model experiments via the summer NSF Research Experiences for Undergraduates (REU) Program.



Jie He joined Georgia Tech in 2018 and is the principal investigator of the Climate Dynamics and Modeling lab group, which seeks to uncover the mechanisms of climate change and variability. Using simple and comprehensive numerical models as the primary tools, the group works at the interface of physics, mathematics, and computer sciences. Its research ranges from atmospheric dynamics and hydroclimate, to air-sea interaction and ocean heat uptake. • RENAY SAN MIGUEL

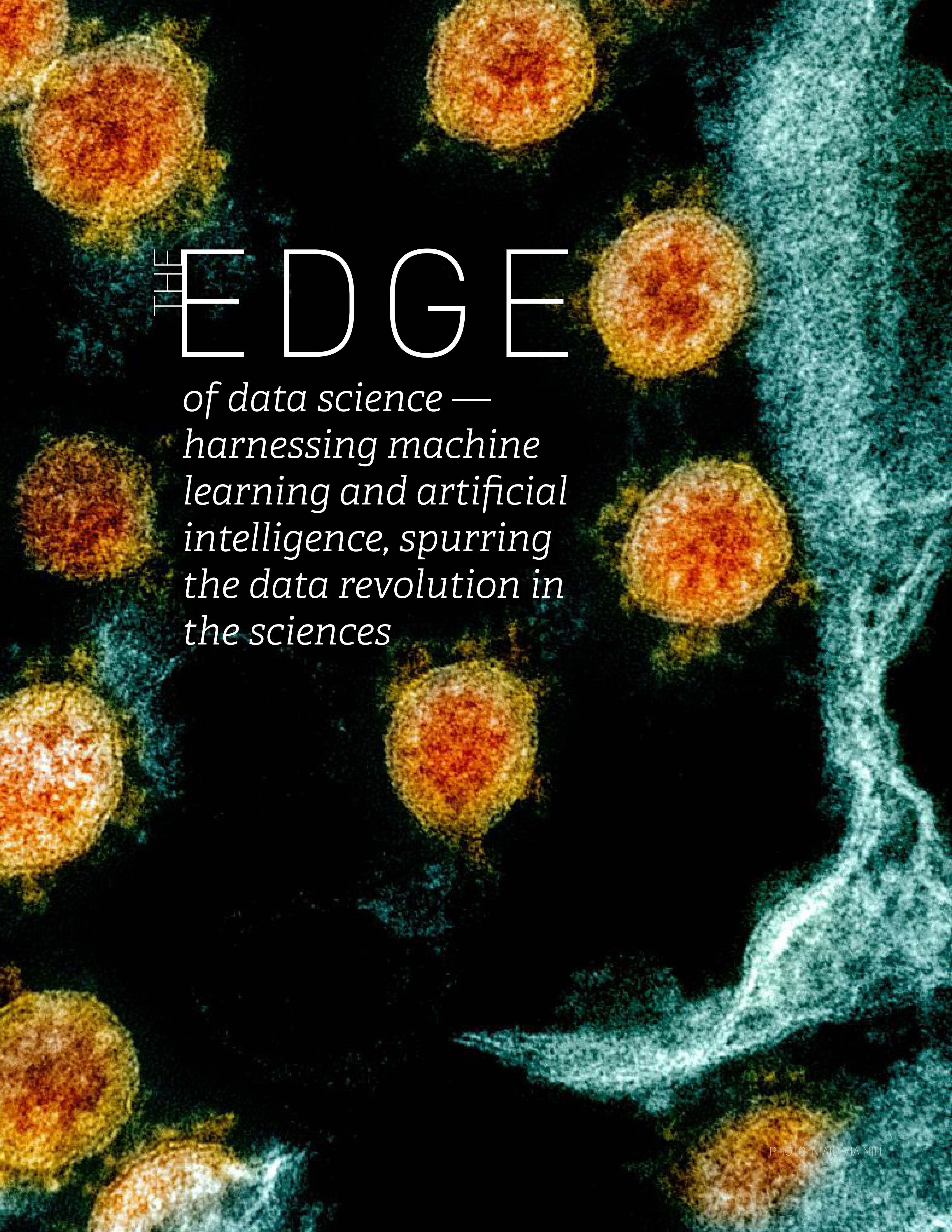


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PHOTO: NIAID VIA NIH

Leveraging Deep Learning

New computational tool lends insights into structure and function of protein complexes

From the muscle fibers that move us to the enzymes that replicate our DNA, proteins are the molecular machinery that makes life possible.

Protein function heavily depends on their three-dimensional structure, and researchers around the world have long endeavored to answer a seemingly simple inquiry to bridge function and form: If you know the building blocks of these molecular machines, can you predict how they are assembled into their functional shape?

This question is not so easy to answer. With complex structures dependent on intricate physical interactions, researchers have turned to artificial neural network models — mathematical frameworks that convert complex patterns into numerical representations — to predict and "see" the shape of proteins in 3D.

In a paper published in *Nature Communications* this past spring, researchers at Georgia Tech and Oak Ridge National Laboratory built upon one such model, AlphaFold 2, to not only predict the biologically active conformation of individual proteins, but also of functional protein pairings, known as complexes.

The work could help researchers bypass lengthy experiments to study the structure and interactions of protein complexes on a large scale, said **Jeffrey Skolnick**, Regents' Professor and Mary and Maisie Gibson Chair in the School of Biological Sciences and one of the corresponding authors of the study, adding that computational models such as these could mean big things for the field.

If these new computational models are successful, Skolnick said, "it could fundamentally change the way biological molecular systems are studied."

Researchers Jeffrey Skolnick (left) and Mu Gao at the Engineered Biosystems Building at Georgia Tech. JESS HUNT-RALSTON

Primed for protein prediction

Created by London-based artificial intelligence lab DeepMind, AlphaFold 2 is a deep learning neural network model designed to predict the three-dimensional structure of a single protein given its amino acid sequence.

"To us, what is striking about AlphaFold 2 is that it not only makes excellent predictions on individual protein domains (the basic structural or functional modules of a protein sequence), but it also performs very well on protein sequences composed of multiple domains," Skolnick said. And so with the ability to predict the structure of these complicated, multi-domain proteins, the research team set out to determine if the program could go a little further.

"The physical interactions between different [protein] domains of the same sequence are essentially the same as the interactions gluing different proteins together," **Mu Gao**, senior research scientist in the School of Biological Sciences and the paper's corresponding author, added. "It quickly became clear that relatively simple modifications to AlphaFold 2 could allow it to predict the structural models of a protein complex."

> ***"Deep learning is changing the way one studies a biological system."***
>
> *Jeffrey Skolnick, School of Biological Sciences*

> *"These computational models now provide insights into the molecular mechanisms for how this biomolecular system works."*
>
> Mu Gao, School of Biological Sciences

To explore different strategies, **Davi Nakajima An**, an undergraduate in the School of Computer Science at Georgia Tech, was recruited to join the team's effort.

Instead of plugging in the features of just one protein sequence into AlphaFold 2 per its original design, the researchers joined the input features of multiple protein sequences together. Combined with new metrics to evaluate the strength of interactions among probed proteins, their new program AF2Complex was created.

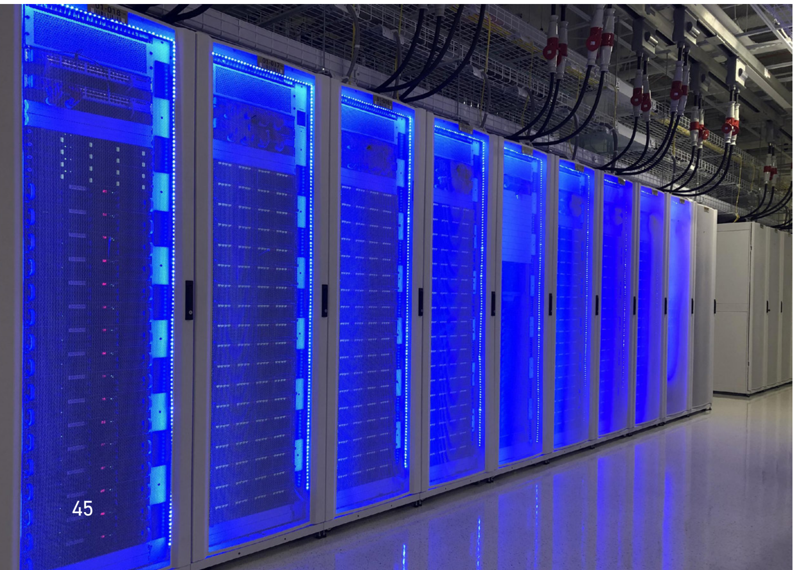
Charting new territory

To put AF2Complex to the test, the researchers partnered with the high-performance computing center, Partnership for an Advanced Computing Environment (PACE), at Georgia Tech, and charged the model with predicting the structures of protein complexes it had never seen before.

The modified program was able to correctly predict the structure of over twice as many protein complexes as a more traditional method, called docking. While AF2Complex only needs protein sequences as input, docking relies on knowing individual protein structures beforehand to predict their combined structure based on complementary shapes.

"Encouraged by these promising results, we extended this idea to an even bigger problem, which is to predict interactions among multiple arbitrarily chosen proteins, e.g., in a simple case, two arbitrary proteins," Skolnick said.

In addition to predicting the structure of protein complexes, AF2Complex was charged with identifying which of over 500 pairs of proteins were able to form a complex at all. Using newly designed metrics, AF2Complex outperformed conventional docking methods and AlphaFold 2 in identifying which of the arbitrary pairs were known to experimentally interact.



To test AF2Complex on the proteome scale, which encompasses an organism's entire library of proteins that can be expressed, the researchers turned to the Summit Oak Ridge Leadership Computing Facility, the world's second largest supercomputing center. "Thanks to this resource, we were able to apply AF2Complex to about 7,000 pairs of proteins from the bacteria *E. coli*," Gao shared.

In that test, the team's new model not only identified many pairs of proteins known to form complexes, but it was able to provide insights into interactions "suspected but never observed experimentally," Gao said.

Digging deeper into these interactions revealed a potential molecular mechanism for protein complexes that are particularly important for energy transport. These protein complexes are known to carry hemes, essential metabolites giving blood its dark red color.

Using AF2Complex's predicted structural models, **Jerry M. Parks**, a senior research and development staff scientist at Oak Ridge National Laboratory and a collaborator in the study, was able to place hemes at their suspected reaction sites within the structure. "These computational models now provide insights into the molecular mechanisms for how this biomolecular system works," Gao said.

"Deep learning is changing the way one studies a biological system," Skolnick added. "We envision methods like AF2Complex will become powerful tools for any biologist who would like to understand molecular mechanisms of a biosystem involving protein interactions." • AUDRA DAVIDSON

AF2Complex is an open-source tool available to the public. Research supported by Department of Energy, the National Institutes of Health.

The initial development of AF2Complex was done at the Partnership for an Advanced Computing Environment (PACE) computing center of Georgia Tech, pictured here in the CODA Data Center. PAUL MANNO/PACE

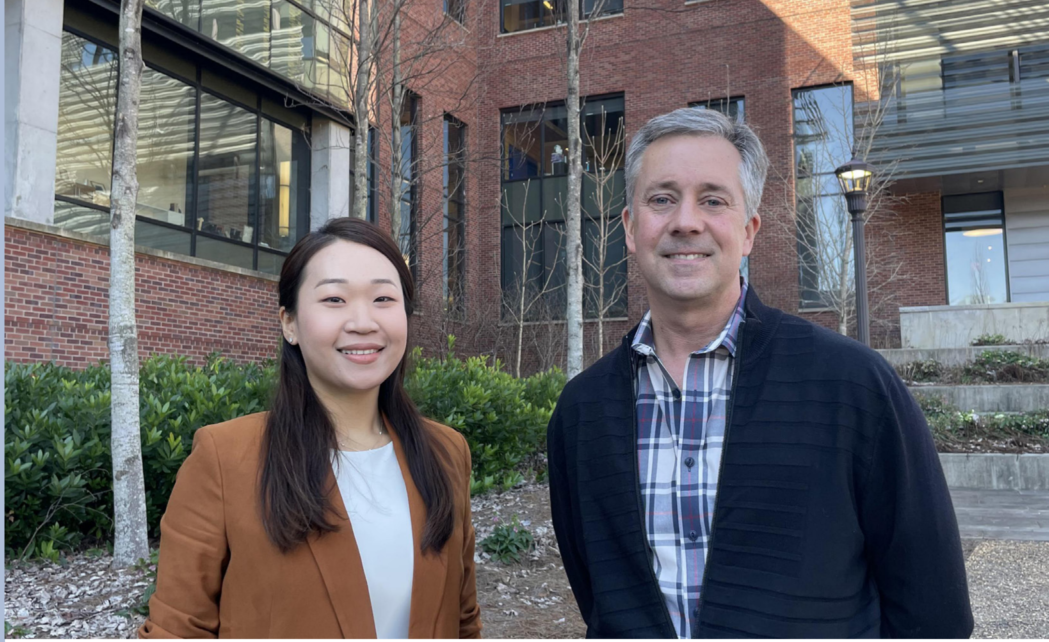
AI Tool Pairs Protein Pathways with Clinical Side Effects

Skolnick and team win stage of NIH NCATS competition

Jeffrey Skolnick is also part of an award-winning National Institutes of Health (NIH) effort to create innovative, AI-powered platforms for discovering new pain management drugs — and for identifying immediate solutions. The competition is staged by NIH's NCATS (National Center for Advancing Translational Sciences) to address the U.S. opioid public health crisis.

A team with Skolnick, **Hongyi Zhou**, senior research scientist in the School of Biological Sciences; **Andre Ghetti** with ANABIOS Corporation; and **Nicole Jung** with Karlsruhe Institute of Technology in Germany was one of four winning the 2020 (NCATS) ASPIRE (A Specialized Platform for Innovative Research Exploration) Challenge, Stage 2, Milestone 1 Award. Skolnick and Zhou also won the previous stage.

Their platform, "Development of a Comprehensive Integrated Platform for Translational Innovation in Pain, Opioid Abuse Disorder and Overdose," faces the final stage, Prototype Delivery, Independent Validation and Testing this year.
• RENAY SAN MIGUEL



Graduate student Kara Keun Lee (left) and Professor King Jordan. JERRY GRILLO

Tackling Cancer Health Disparities

Thanks to better diagnostics, therapeutics, and care, the overall cancer mortality rate has plummeted in the past 20 years. But cancer survival disparities stubbornly persist along racial and ethnic lines, demanding a firmer grasp of the underlying mechanisms at play, which would ideally result in better outcomes for populations disproportionately burdened by the disease.

Scientists at Georgia Tech are tackling this complex, multi-layered problem, with recent findings that have blurred the line between nature and nurture — providing a potential link between the genetic and epigenetic contributions to disparities.

The researchers' recent findings point to epigenetic mechanisms – not genetics – as the primary culprit in cancer survival disparities. Epigenetic changes, which can alter the structure of DNA and affect how genes are expressed, can be heavily influenced by the environment around us and the food that we eat.

"That means the environment may actually change how genes are expressed," said **King Jordan**, professor in the School of Biological Sciences and principal investigator of the study.

The research is a collaboration of Jordan and School of Biological Sciences Professor **John McDonald**, along with graduate student **Kara Keun Lee**, the study's lead author; and **Leonardo Mariño-Ramírez**, head of Genomic and Epidemiology Sciences at the NIH's National Institute on Minority Health and Health Disparities, which helped fund the study.

"Following that epigenetic trail, or at least the logic of it, looking at how genes and the environment interact to shape health disparities will be a big focus of my lab going forward," Jordan said.
• JERRY GRILLO

Blending Old and New Schools

Machine learning mixes with traditional science principles

Machine learning came along at just the right time. The world is awash in more data than ever before, and computer algorithms — that can learn and improve as they perform data analysis — promise to help scientists handle that information overload.

Yet researchers who think that machine learning by itself can help solve complex problems in science, engineering, and medicine should strive for a more balanced approach, says **Roman Grigoriev**, part of a School of Physics team with new research suggesting a hybrid approach for conducting science that blends new era technologies, old school experimentation, and theoretical analysis.

The research suggests faster solutions to complex, data-intensive riddles involving such issues as cancer, earthquakes, weather forecasts, and climate change.

"It's a combination of existing theoretical understanding — as well as experimental data with machine learning," said Grigoriev, professor and lead investigator of the Dynamics and Control Group. "Oftentimes people who do machine learning kind of forget about theoretical understanding and rely almost totally on data. It's relatively simple, but when there's a lot of data and not enough structure in that data, that approach is bound to fail."

Grigoriev explained that there's often just too much data to meaningfully analyze, at which point "the problem becomes intractable. Essentially, harnessing appropriate domain knowledge is critical for finding structure in the data."

The team's study, "Robust learning from noisy, incomplete, high-dimensional experimental data via physically constrained symbolic regression," is published in *Nature Communications*. Fellow School of Physics researchers who worked on the paper include Professor **Michael Schatz** and former graduate students **Logan Kageorge**, assistant professor at Brenau University; and **Patrick A.K. Reinbold**, data scientist at Lowe's Companies, Inc.

The problem with high-dimensional data

Machine learning uses computer algorithms to find patterns in data, but "most popular machine learning approaches present results in a form that is hard to interpret and explain," Grigoriev said. "Unless you understand the how and the why, you can't really say you understand a problem."

Understanding and predicting complicated behaviors — by crunching a lot of dense, rich data — can help with fundamental and practical problems in science arenas like weather forecasting and characterizing cardiac arrhythmias.

The problem is that most of those arenas involve "high-dimensional" data, which means exactly what it sounds like: data with a lot of dimensions or variables, sometimes millions of them.

The dimensionality of the data is so large that "you get lost and it's hard to see any trends," Grigoriev said.

His team has come up with a hybrid approach that blends machine learning with elements of the traditional process of scientific discovery. That means a theoretical description, observations, designing experiments to test the description, and "then going back and forth between improving the theories, and designing new experiments. That's been the traditional approach for hundreds of years."

Of course, the foundation of scientific understanding and progress relies on that scientific method — the combination of theory and experimentation. "They're not developed just based on the data. They are developed using both existing knowledge as well as some general fundamental laws."

Roman Grigoriev, professor and corresponding author.

A fluid dynamics experiment shows small fluorescent particles carried along by the flow. The particles represent the types of data used in the School of Physics study. ROMAN GRIGORIEV

An approach that spotlights the beauty of equations

Constraining the data to include just those variables that pertain directly to the experiment in question is vital in working with high-dimensional data, Grigoriev said.

"What this approach allows you to do is identify a simpler model that uses the variables you need. It's a simplified description that applies to a particular situation, but obtained using data that's computational or experimental. It can do both."

The result is represented in a mathematical model, Grigoriev said, and "once you see those equations, you understand what the variables are. The equations certainly help explain the essence of a physical problem."

His team's approach was validated in the research with a fluid dynamics experiment. A thin layer of liquid was suspended in a rectangular tank, with magnetic and electrical fields shot through it to create what physicists call a turbulent flow — irregular shifts happening within the fluid layer that can rapidly change direction and magnitude.

The team used their hybrid approach to analyze the accessible data, in this case the velocity of the liquid. Subsequently, they were able to reconstruct variables that couldn't be measured directly, like liquid pressure and force.

This is the beauty of the equations — how much they allow you to do, Grigoriev said.

"What we do get is an equation, or set of equations, which are in a familiar form. We know how to explain, how to solve the problem using these equations. This is the nice thing about this approach. We're working with variables whose meaning we understand; we know how to interpret them."

The team believes the study's results will lead to advances like faster, more accurate ways to make predictions of complicated behavior in those large, real world problems in science, engineering, and medicine. For example, as the research team shared, "the ability to identify and quantify important patterns and sequences in atmospheric turbulence should enable weather forecasts that are more accurate and more rapid than those currently possible today." • RENAY SAN MIGUEL

Research supported by the National Science Foundation.

"Oftentimes people who do machine learning kind of forget about theoretical understanding and rely almost totally on data. It's relatively simple, but when there's a lot of data and not enough structure in that data, that approach is bound to fail."

Roman Grigoriev, School of Physics

Meet Professor Santosh Vempala

Director of the Algorithms, Combinatorics, and Optimization Program (ACO) at Georgia Tech

As one of the best discrete mathematics and combinatorics graduate programs in the country, Georgia Tech's Algorithms, Combinatorics, and Optimization doctoral program has long been known for its excellence and rigor.

Newly appointed director **Santosh Vempala** plans to both "ensure that the program maintains its high quality — and make it desirable for a diverse student population."

"The ACO program is special both at Georgia Tech and in the world," said Vempala, who serves as professor and Frederick G. Storey Chair in the College of Computing with joint appointments across the School of Computer Science, School of Mathematics, and the H. Milton Stewart School of Industrial and Systems Engineering (ISyE).

"The community of students, thanks to the dedicated and insightful work of previous directors, is thriving, both while they are here at Georgia Tech and after they graduate. They have been exceptionally successful."

Founded in 1991, the ACO program is housed jointly across the College of Computing, the School of Mathematics in the College of Sciences, and ISyE in the College of Engineering.

The multidisciplinary Algorithms, Combinatorics, and Optimization doctoral program focuses on topics like graph theory, algorithms, discrete optimization — and the interplay between the three.

Focused on topics like graph theory, algorithms, and discrete optimization — and the interplay between the three — the program has deeply embraced its multidisciplinary nature, essentially eliminating "the traditional walls that usually separate academic units" by encouraging faculty members to advise students regardless of departmental affiliation.

ACO "brings together three disciplines that are fundamentally related," Vempala explained. "Its course structure enables students to understand phenomena from all three perspectives and learn to use tools from all of them."

Vempala has been involved with the ACO program since he joined the Georgia Tech faculty in 2006, advising many students in ACO, as well as serving on committees within the program.

"Professor Vempala's experience at Georgia Tech, including his prior service as associate director of the ACO program, means that he is uniquely qualified to serve as director," said **David Collard**, professor in the School of Chemistry and Biochemistry and senior associate dean in the College of Sciences. "The program is highly regarded nationally and internationally. It attracts superb students from around the world and provides exceptional educational opportunities. I look forward to its continued success under Professor Vempala's leadership."

Santosh Vempala, professor and Frederick G. Storey Chair, and director of the ACO program at Georgia Tech.

From algorithms, randomness to ACO

Vempala received his Ph.D. in Algorithms, Combinatorics, and Optimization at Carnegie Mellon University before spending a year as a Miller Fellow at University of California, Berkeley and a decade as a professor of mathematics at the Massachusetts Institute of Technology. Upon joining the faculty at Georgia Tech, Vempala served as the founding director of Tech's Algorithms and Randomness Center. He is a fellow of both the Association for Computing Machinery and the American Mathematical Society.

Describing his research as "studying the nature of computation, and its limits," Vempala's work ranges from theoretical to applied. Often entailing searching for efficient algorithms to solve fundamental mathematical and computational problems, his work also has applications such as such as trying to explain how the mind (perception, cognition, language, learning) emerges from the brain (neurons, synapses). "The best possible algorithms for basic problems — such as solving linear systems and linear programming — are still waiting to be discovered," he said.

Along with continuing ACO's longstanding record of research and academic excellence, Vempala is also keen to foster community and another 'factor' across the ACO community.

"I am looking forward to working with my colleagues in Computer Science, Mathematics, and ISyE, to building an atmosphere of scientific collegiality and open curiosity for faculty and students, and to having more social events with a high fun factor."

In addition to research and leading ACO, Vempala is an active instructor who teaches Computability and Algorithms, Machine Learning Theory, Optimization and Sampling, and Computation and the Brain courses across campus.

"Teaching takes a lot of effort for me with an hour of lecture needing several hours of preparation, but it is consistently rewarding — each lecture is an opportunity to understand something better; each student is an opportunity to see something from a new angle."
• AUDRA DAVIDSON

Wenjing Liao Wins NSF CAREER Award

School of Mathematics Assistant Professor **Wenjing Liao** is the latest College of Sciences faculty member to receive a National Science Foundation Faculty Early Career Development Program (CAREER) Award.

Liao, who researches high dimensional data analysis and machine learning, will use funding to develop easier ways of solving complex datasets, and to establish undergraduate programs linking machine learning research with data science education.

The CAREER Award provides funding for five years and is one of the most significant grants that a scientist can receive early in their profession.

"I am very grateful to the NSF for its support," said Liao. "This CAREER Award will not only support my team's efforts in the area of computational math and data analysis, but it will also support the training of the future data analysis workforce by involving graduate and undergraduate students."

Through the education grant component, Liao hopes to build an undergraduate "Bridge" program for math and data science students to assist with the transition from Georgia Tech to careers in academia and industry, and to organize a young researchers workshop on mathematical foundations of machine learning.

She also hopes to recruit more math undergraduates from diverse backgrounds across the greater Atlanta area — and to design special math and data science research projects for students in the NSF's Research Experiences for Undergraduates program, through which she has mentored visiting and current Georgia Tech students leading their own research projects.
• RENAY SAN MIGUEL

Modeling Water-Cleansing Wetlands in Extreme Weather

The cycle of rising temperatures leads to increases in precipitation as well as droughts. But what impact will these weather extremes, especially heavier precipitation, have on the Earth's most effective water cleansers – wetland sediments?

That question is driving a new $1 million, three-year grant awarded to an interdisciplinary team of geochemistry, biology, and applied mechanics experts at Georgia Tech.

The award is part of the Department of Energy's $7.7 million funding of 11 studies to improve the understanding of Earth system predictability and the Department's Energy Exascale Earth System Model, a state-of the-science climate model.

By better understanding how wetlands work, the researchers hope to shed light on how wetlands will function with more frequent and more intense rainstorms.

"A lot of work has been done in polar regions where there has been melting because of global warming, which has been shown to release a lot of methane. That's the main motivation behind the work we're going to do," said the project's principal investigator, **Martial Taillefert**, a geochemist and professor in the School of Earth and Atmospheric Sciences.

Taillefert will characterize the physical and chemical processes taking place in a wetland, following the chemical response to microbial processes and studying how disturbances in the water cycle affect the release of greenhouse gases, then using that data to fine tune models that predict emissions.

Collaborator **Chloé Arson**, professor of Geosystems Engineering in the School of Civil and Environmental Engineering, will use AI to help build the model, and **Thomas DiChristina**, professor in the School of Biological Sciences, will use genomics to study multiple gene expressions without having to grow the bacteria in a laboratory.

Taillefert and DiChristina have been working on improving Tech's models for predicting these types of processes for over three decades. In developing this scalable model, they hope to better analyze and ultimately predict where and when wetland sediment disruptions are most likely to occur.

• ANNE WAINSCOTT-SARGENT

SAVANNAH RIVER NATIONAL LABORATORY ENVIRONMENTS

Tech Joins NSF's Next Generation of Research Cyberinfrastructure Ecosystems

Georgia Tech is among a collaborative team of institutions awarded a $5 million OpenCI (Open Cyberinfrastructure) grant from the National Science Foundation to help support the Advanced Cyberinfrastructure Coordination Ecosystem Services and Support (ACCESS) program.

ACCESS is the NSF's next generation research cyberinfrastructure support mechanism to serve the evolving needs of the scientific community nationwide. Cyberinfrastructure — highly connected high-performance computing systems that support advanced data acquisition, storage, and management — is critical for information sharing and research collaboration.

Lizanne DeStefano, executive director of the Center for Education Integrating Science, Mathematics and Computing (CEISMC) and professor in the School of Psychology, is one of the co-principal investigators of this five-year award that will support the collective and coordinated efforts of four other NSF grants awarded to various institutions to address resource allocations, training, operations, and measurement services of the ACCESS program.

"With cyberinfrastructure for academic research computing continuously becoming more sophisticated, it is imperative that we can efficiently connect researchers with the data, technologies, and expertise available to help bring their innovative ideas to fruition," DeStefano said.

ACCESS is a follow-up to NSF's Extreme Science and Engineering Discovery Environment (XSEDE), a virtual organization created in 2011 that integrates and coordinates the sharing of advanced computing resources, data, and expertise with researchers nationally to support science and engineering projects that may not have been possible without the shared resources.

Lizanne DeStefano, professor in the School of Psychology and executive director, Georgia Tech CEISMC.

DeStefano, who has been involved in evaluating cyberinfrastructures for the last 20 years, served as the external evaluator of XSEDE. "XSEDE represented the centralized and coordinated way of allocating research computing services internally which worked well for the last decade," she said. "Now, this external approach of coordinating efforts through a distributed model will provide a new means of establishing shared metrics to better define our effectiveness individually and collectively to guide us forward for maximum impact."

• JOËLLE WALLS

"With cyberinfrastructure for academic research computing continuously becoming more sophisticated, it is imperative that we can efficiently connect researchers with the data, technologies, and expertise available to help bring their innovative ideas to fruition."

Lizanne DeStefano, School of Psychology

Partnering with Savannahians to Implement Data-Driven Solutions

Randall Mathews has an attentive insurance agent to thank.

Part of Mathew's job as the assistant director at Chatham Emergency Management Agency (CEMA) is finding and prioritizing infrastructure to inspect after a flood event, which can be time-consuming and frustrating. In Savannah, the capital of Chatham County, mandatory evacuations are rare — there were none for 15 years between 2000 and 2015. However, by 2017, mandatory evacuations in consecutive years prompted by Hurricanes Matthew and Irma reminded residents, community leaders, and emergency planners just how important it is to have access to timely assessments of hazards during a flood emergency. They could mean the difference between life or death.

In late 2017, Randall bumped into an insurance agent who had just been to a local Rotary meeting in Downtown Savannah where **Russ Clark**, a faculty member at the College of Computing at Georgia Tech, spoke about climate change and sea level rise. Like Mathews, Clark was also passionate about using data to improve climate resilience: his own home in the Savannah area, built only two feet above high tide, was flooded during Hurricane Irma. Concerned about the financial risk the insurance industry bears during extreme weather events, the agent begged Mathews to talk to Clark, and the rest is history.

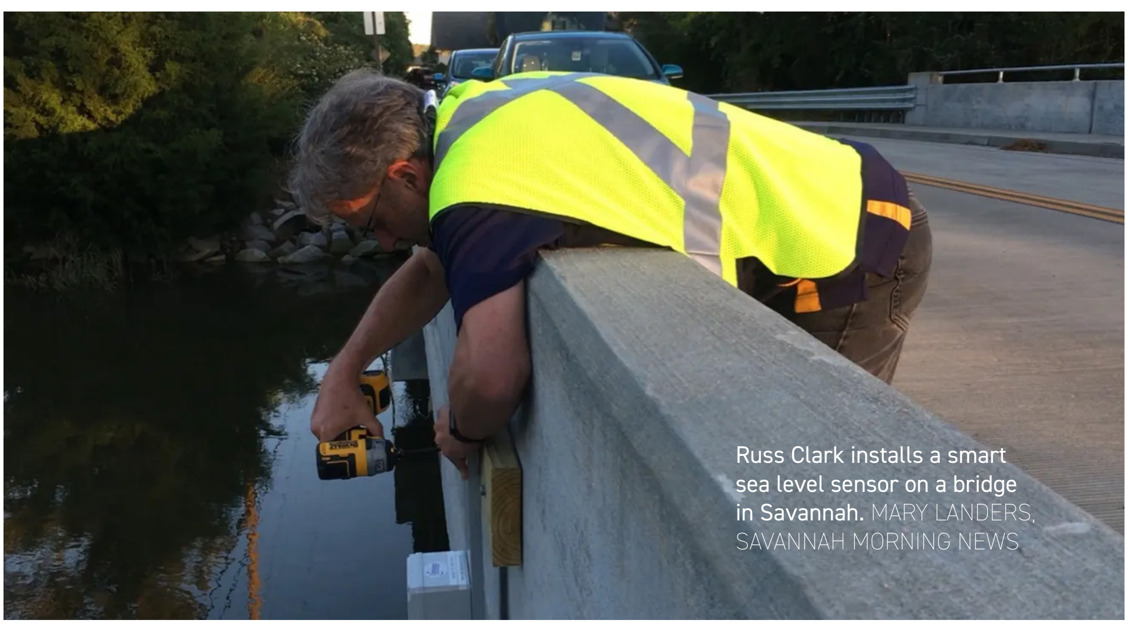
Three years later, Mathews and Clark are co-leads of the Smart Sea Level Sensors (SSLS) team, together with City of Savannah Office of Sustainability director **Nick Deffley** and climate scientist **Kim Cobb**, formerly of Georgia Tech and recently appointed director of the new Institute at Brown for Environment and Society.

Last fall, the team published a dashboard to allow for real-time flood visualization in Chatham County to aid emergency planning and response.

The dashboard draws data from a growing network of 52 internet-enabled sea level sensors installed near waterways and bridges within Chatham County. Designed to use mostly off-the-shelf parts and approximately the size of a shoebox, the sensors were assembled through a partnership with local students and community groups, including the Harambee House, a Savannah-area organization that works with at-risk communities to build capacity around resolving social, economic, and environmental issues.

The sensors were installed based on a number of factors, including how close they are to critical facilities such as schools and hospitals, in addition to how well they can serve vulnerable communities. A dedicated engagement team has also worked with graduate student **Jorge-Mario Lozano** to determine future sensor locations — using a blended approach that combines geographic information systems (GIS) with network optimization algorithms and innovative metrics related to flood likelihood and social vulnerability.

Special significance is placed on bridges because they are often the bottlenecks in evacuation and emergency response-related activities. However, after a flood emergency, bridges are critical to recovery efforts but must be deemed structurally sound prior to being cleared for use. Bridges could have their foundations compromised after flood events, creating a hazard for fire trucks or emergency vehicles, and later, for returning residents. The state of Georgia has a limited number of bridge inspecting teams to monitor the entire coast, but there are 160 bridges in Chatham County alone; concrete data about which bridges were exposed to flooding can greatly speed operations.



Russ Clark installs a smart sea level sensor on a bridge in Savannah. MARY LANDERS, SAVANNAH MORNING NEWS

A "tipping bucket" rain gauge (background) is wired to a sea level sensor (foreground). RUSS CLARK

The research team has since worked to minimize uncertainties by strategically deploying more sensors in areas that are poorly covered by the existing sensor network, and to communicate the various sources of uncertainty to decision-makers.

They are joined by intern **Austin Ang**, a Georgia Tech undergraduate student who is bringing his work with the project full circle: as a highschooler, Ang had been one of the student volunteers at Jenkins High School who had assembled the team's first sensors and kickstarted the project.

"I joined the project because I formerly worked on the Sea Level Sensors in high school and wanted to re-contribute to the project with some of the knowledge I gained in college," Ang said. "I am hoping to further my software engineering skills and to make a difference in my community while doing so."

The team's work on the portal, which is published at sealevelsensors.org, is funded by the Georgia Department of Natural Resources Coastal Incentive Grant program. • ALEX IP

This story is supported by a grant from the Institute for Journalism and Natural Resources, and the National Association of Science Writers.

Faces of Research: David Sherrill

Meet **David Sherrill,** Regents' Professor in Chemistry and Computational Science, and associate director of Georgia Tech's Institute for Data Engineering Science (IDEaS) — one of Georgia Tech's 10 interdisciplinary research institutes within our research enterprise.

What is your field of expertise and why did you choose it?

I work at the intersection of chemistry, algorithms, and data science. I loved chemistry in high school and college, but I turned out to be a klutz in the lab. Fortunately, I discovered graduate programs in theoretical and computational chemistry.

What's unique about Georgia Tech's research institutes?

Georgia Tech has deep expertise in many fields, but often the most relevant investigators for an interdisciplinary problem are spread across multiple units. The Georgia Tech research institutes help connect these researchers.

What kind of impact is your research having on the world?

Computer hardware and algorithms keep getting faster, and machine learning provides a whole new set of tools for modeling scientific data. I am excited to lead a group that creates new algorithms and software that leverage these advances and apply them to chemical problems, like drug discovery and crystal engineering.

What do you like to do in your spare time when you are not working on your research or teaching?

I frequently take hikes around Atlanta on Saturdays. I also enjoy movies and strategy games. •

Working on the Future of Work

A conversation with Ruth Kanfer

The School of Psychology professor has a book out, a highly cited paper, and a new project to study artificial intelligence's potential for enhancing adult learning.

In 2019, when School of Psychology Professor **Ruth Kanfer** was working on a book that would feature the latest science on aging and age-diverse workforces, Kanfer and her three co-authors wanted to write a manual of sorts for supervisors, human resources managers, and organizational leaders — not necessarily academics and scholars.

Then 2020 happened, and the Covid-19 pandemic had other ideas on how to influence *Ageless Talent: Enhancing the Performance and Well-Being of Your Age-Diverse Workforce* (Routledge, 2021).

"As we were writing, we started thinking about what managers would need to know post-pandemic, how it was affecting workers of different age groups," said Kanfer, a member of the Industrial/Organizational Psychology program and founding director of Georgia Tech's Work Science Center. "Towards the end, we wrote about possible implications and what issues might come up."

Motivating workers in a disrupted and transformed workforce is one of those issues, she said.

Motivation related to work has long been Kanfer's primary research interest. Kanfer, who first came to Georgia Tech in 1997, was recently notified that a 2017 paper in which she was the lead author, "Motivation related to work: A century of progress," remains in the top ten list of downloaded articles from the *Journal of Applied Psychology*. "It's one of the leading journals in the broad area of applied psychology," said **Tansu Celikel**, professor and chair of the School of Psychology.

Kanfer will continue to study work motivation in the National Science Foundation's new National AI Institute for Adult Learning in Online Education (AI-ALOE). Led by **Myk Garn** of the Georgia Research Alliance, University System of Georgia; and **Ashok Goel**, professor in the College of Computing at Georgia Tech, the AI-ALOE Institute will study foundational AI issues and develop AI systems to enhance adult learning.

Kanfer recently spoke with the College of Sciences about AI-ALOE, where the future of the workforce is heading post-pandemic, and thoughts on whether certain demographics of workers will return to the workforce — and office.

"The issue of worker well-being — there wasn't really a lot of interest in this prior to the pandemic. It was more about productivity and new technologies. The pandemic changed that. If you want to preserve your workforce, not just the older workforce, you must pay attention to well-being, and that has stuck."

Ruth Kanfer, School of Psychology

What are the biggest lessons for you on how the pandemic changed the workplace and workforce, particularly the aging workforce?

There are four lessons. First, the pandemic caused a real upsetting of the apple cart in terms of labor shortages. That does have to do with the aging workforce. The 55 and older group was the fastest-growing segment of the workforce prior to the pandemic, so you can imagine that their sudden departure would have an outsized impact. I had a manager once say to me that 40 percent of the workplace on the front lines of their company was over the age of 55, but if they managed retirements carefully, it would be fine.

Well, during the pandemic no one could manage workforce exits well, and the pandemic caused a lot of early retirements. Whether those folks will come back is unknown, but the loss was substantial. Almost a third of the workforce shortage comes from older workers who did not want to be exposed to the virus or chose to retire a bit earlier than planned.

Second is the issue of worker well-being. There wasn't really a lot of interest in this prior to the pandemic. It was more about productivity and new technologies. The pandemic changed that. If you want to preserve your workforce, not just the older workforce, you must pay attention to well-being, and that has stuck. I think we are much more focused on worker well-being than we were pre-pandemic.

The third lesson comes from the impact of technology. The pandemic caused a massive shift to remote work for many people and has accelerated the development and implementation of new technologies. But it is very clear that technological developments cannot fully replace human workers. Technology didn't obliterate jobs, it changed jobs, and it's still doing that. What technology can't do well, yet, in implementation, is make complex decisions about things that are not black and white. Not yet.

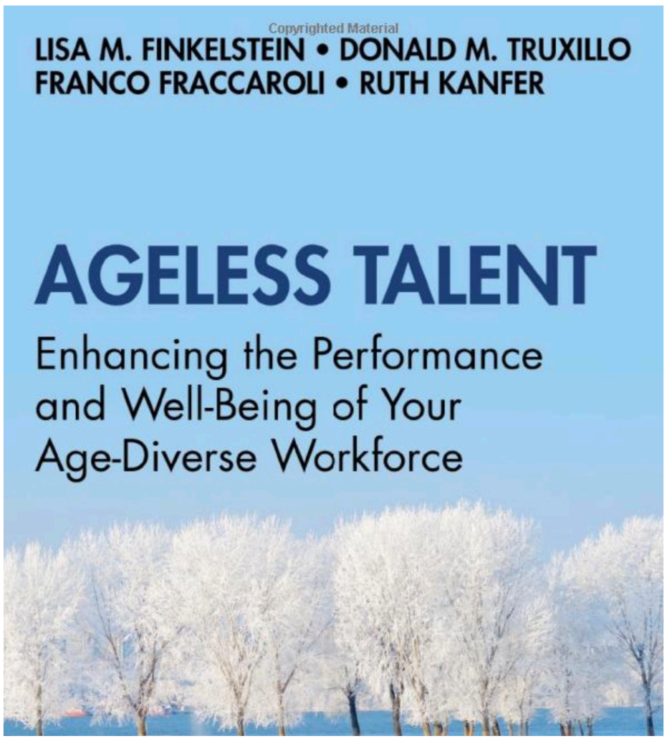
Technology also isn't very good with factoring in emotions. Tech is a double-edged sword. It has helped people, and it has provided tools. It has made some jobs more interesting, some less interesting. It's also pushed humans into new learning, and usually with the workforce, most of the learning you do is on the job after graduation. It used to be that on the job, someone older would train you, but that is often not the case when it comes to implementing new technologies. Now it's continuous learning, and new skill-learning as part of your job is front and center.

The fourth lesson has to do with work arrangements. Sending everybody home to do remote work has upended assumptions that organizations have long had — that you need to have your employees at the workplace, that you need to be continuously supervising them, or you're not going to achieve your goals. Well, during the pandemic workers were still productive. And this has left a lot of organizational leaders asking, what are we going to do with all this real estate if workers want to be remote? And if I let my workers be

Professor and Work Science Center Director Ruth Kanfer.

remote, how am I going to bind them psychologically to the organization? This has not been a temporary disruption. It has changed fundamental motives about work, and what binds people to organizations. I think organizations aren't used to thinking that what binds their employees to them are human relationships. It's much easier to think in terms of compensation and perks and the more material goods.

Prior to the pandemic, the question was should we be in cubicles or open space in offices. Post-pandemic, I don't think that's as relevant. Many people won't do most of their work in the office. They will go to the office to see other people and connect themselves to the organization. Jobs are no longer eight-to-five; they can and often do work at home.



The cover of *Ageless Talent*, which Kanfer co-authored with colleagues before and throughout the pandemic.

Ageless Talent was published in 2021. What have you heard from organizations and managers who have read the book?

We have received very positive comments and the book has been popular with a wider audience, so it's sold well on Amazon.

The advantage of the book is it doesn't just tell you what we know, but how to use what we know in the workplace. And realistically what some of the challenges are that you're going to face when you're trying to manage and support balance.

What are those challenges? What's the one big takeaway from *Ageless Talent* that would help organization leaders manage their age-diverse workforces?

Age diversity is here to stay. First, people are living longer and working longer, often for financial reasons (insufficient financial resources for retirement), but often also for non-financial reasons such as to structure time, maintain social relationships, and sustain professional identity. Second, as jobs require less physical labor due to automation, and organizations increase flexibility in employment options — flexible scheduling, contract work — it is no longer unusual to see work teams made up of three or more generations/cohorts.

Knowing the facts about aging and using PIERA (Planning, Implementation, Evaluation, Reflection, Adjustment — a key strategy from the book) to manage an age-diverse workforce helps create a stronger, more collaborative workplace culture. The book provides important information about how and why age differences manifest in the workplace, and a clear set of evidence-based tools to use when managing an age-diverse workforce.

What is it about the aging workforce that makes it ripe for research, particularly post-pandemic?

One of the things about studying the aging workforce is that when young people first enter the workforce, they typically focus on doing well, learning a lot, and advancing their careers. They're on a trajectory.

In contrast, in an older workforce — let's take pilots for example — people have different levels of expertise, different patterns of age-related decline in cognitive abilities, and very different non-work lives. A lot of motives can be satisfied by spending time at home. Others don't have that option. It's a much more complicated environment for being able to predict and understand things like retirement, and how people want to retire.

One of the things we have learned is that people are motivated. They generally don't lose motivation for jobs that allow them to have some autonomy, control, and to make a meaningful contribution. They remain motivated, and there's a lot that organizations can do to reinforce that with support and training and reducing age stereotypic norms. That will keep older people interested in continuing in the workforce. That's why I think some of them will come back.

Speaking of motivation, it was the topic of a paper you co-authored five years ago that is still on the Top Ten Most Cited List from the *Journal of Applied Psychology*. Motivation also gets its own chapter in *Ageless Talent*. What are the challenges in motivating an age-diverse workforce?

When I started my career, I focused on understanding the role of motivation in complex skill learning for jobs like air traffic control. I was really interested in the processes by which motivation impacts performance, irrespective of adult development. Drawing from motivation theory and cognitive psychology we examined when and for whom motivation during training might wane. Over the years there has been a gradual shift away from understanding motivation processes and toward understanding the why of motivation — what are the reasons? How do reasons for action affect what people do and how hard they try to accomplish a goal? For example, some of this has to do with mindset. If you approach a task with the idea of learning, then when you make errors early on, it doesn't cause you to drop out. On the other hand, if you have different expectations — you want to look good to your supervisor — and you make errors early, you're much more likely to back away from further learning. Holding a learning mindset is really important when you're training working adult learners to use new technologies. Adults in the workplace always want to look competent. We know a lot more now about older workers, and we know that self-paced training is much preferred to instructor-based pacing. Mature individuals work at different speeds. You want to take advantage of that, which can really change the nature of training design.

I think we've learned a lot about adult development that we can use to help people. Particularly about "why" people exert effort. It's usually not a single reason, but what motive is dominant. Am I doing this to get a promotion, because I like to learn, to help others, or maybe to teach younger people? That last generativity motive is typically stronger in middle to late adulthood.

You're part of the NSF's cross-disciplinary, collaborative National AI Institute for Adult Learning and Online Education (AI-ALOE) at Georgia Tech. Tell us about that research and what you hope to accomplish there.

The broad goal of AI-ALOE is to develop new AI technologies to improve adult learning. That's why I'm involved. I'm interested in adult learning for reskilling, upskilling, and lifelong learning. I am using my expertise in age-related changes in cognitive and motivational/affective processes to help in the development of agents and tools that will help us with theory of mind and benefit adult learners and teachers. The project is less than a year old, and it's a five-year project. It's an ambitious project to develop these technologies, and what the Institute learns and develops is expected to be useful to public and private sectors who are concerned with building the 21st century workforce.

The Institute is not just about older people, but adults of all ages who will need or want to update or retrain. The Institute focuses on adult learning, which is not the same as K-12 learning. Adults have different goals and issues. Adults are typically very practically oriented with specific work goals. Adults are impatient. They have other things to do in their life. You want learning to be efficient.

AI offers the potential for personalized learning at scale. Personalization is critical for inclusivity and for helping people with different levels of knowledge and learning styles; at scale is important given the rapidity of changes in the workplace that demand new skills. Online learning has taken hold in part because it is asynchronous. That makes the learning experience flexible. For adult learning to be successful, it must also be relevant, affordable, and enjoyable.

• RENAY SAN MIGUEL

> ***"One of the things we have learned is that people are motivated. They generally don't lose motivation for jobs that allow them to have some autonomy, control, and to make a meaningful contribution. They remain motivated, and there's a lot that organizations can do to reinforce that with support and training and reducing age stereotypic norms."***
>
> *Ruth Kanfer, School of Psychology*

THE EDGE

of microbial dynamics and infection, evolution, astrobiology, and the origins of life

ART: NASA/JPL-CALTECH

An Evolution of Astrobiology

Georgia Tech hosts the nation's astrobiology community during renowned conference focused on the origins of life

Buoyed by Georgia Tech's interdisciplinary research on the origins of life and the possibility of it beyond Earth, three researchers from the Colleges of Sciences and Engineering were the lead organizers for the field of astrobiology's largest national conference.

More than 1,000 abstracts were discussed during AbSciCon 2022. The event takes place every two years, allowing experts to share their research, collaborate, and map the future of their field. AbSciCon, short for Astrobiology Science Conference, is hosted by NASA and the American Geophysical Union (AGU) and took place in downtown Atlanta for 2022.

"We are delighted to welcome NASA and the astrobiology community to AbSciCon 2022, along with aspiring scientists and engineers of all ages for this year's public events," said Dean of the College of Sciences, Sutherland Chair, and AGU President **Susan Lozier** at the event. "This year's theme, 'Origins and Exploration: From Stars to Cells' speaks not only to the breadth of research discovery and solutions within our reach — but also to the collaborative, inclusive community steering the broad future of this field."

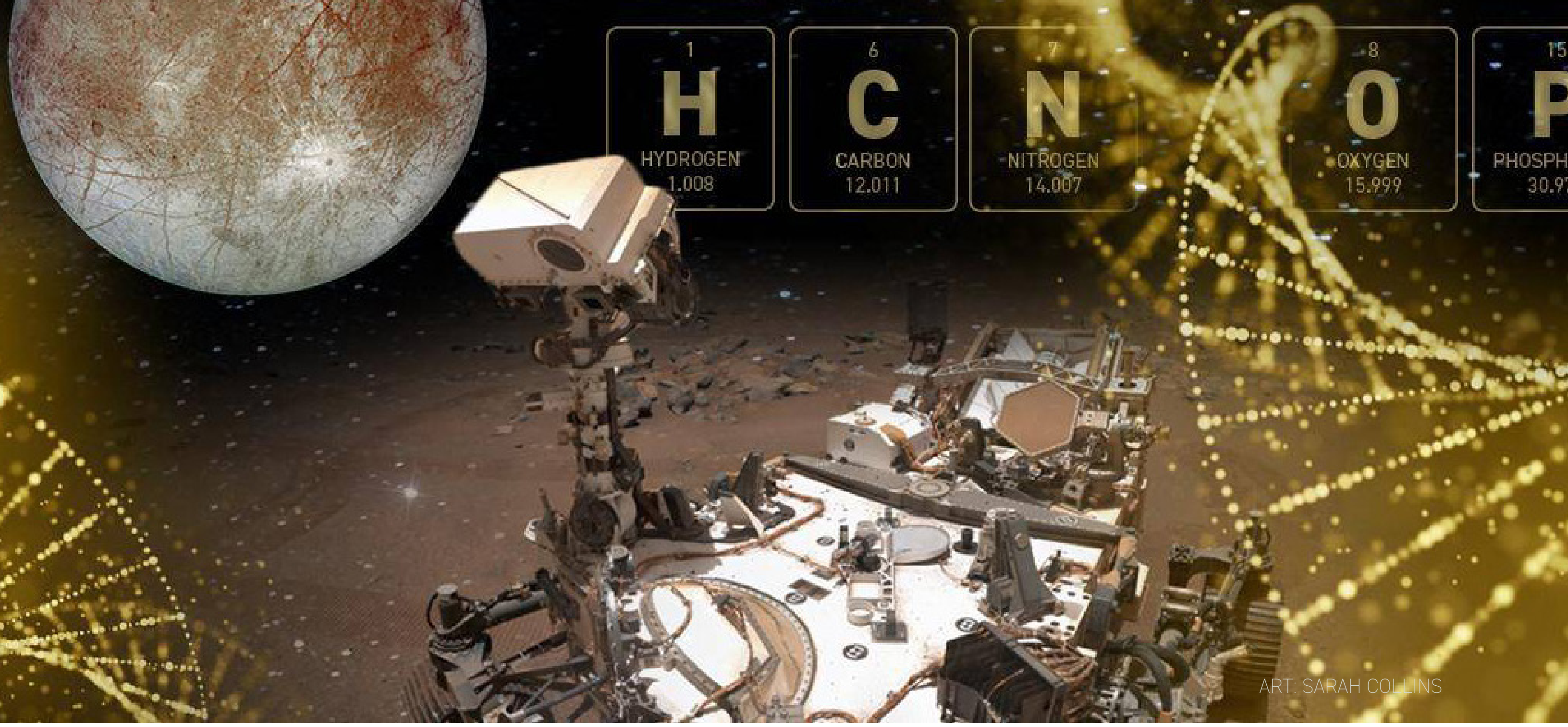
"Georgia Tech's astrobiology community is uniquely positioned within higher education because of the Institute's focus on breaking down silos within our research community," said **Martha Grover**, AbSciCon's general chair and a professor and associate chair for graduate students in the School of Chemical and Biomolecular Engineering. "We have the scientists to explore the origin and the potential of life on moons and planets, while our engineers can create the technology to launch and test."

Grover is on a team recently awarded $1.5 million by the Alfred P. Sloan Foundation for that kind of collaborative research between Georgia Tech scientists and engineers. She and fellow researchers led by School of Chemistry and Biochemistry Regents' Professor **Nicholas Hud** will develop chemical systems that evolve like those in biology — but are made up of synthetic molecules not found in life. The goal is to harness the power of evolution to produce molecules with properties that are currently unattainable.

It was Hud and **Loren Williams** who launched Georgia Tech's first substantial forays into astrobiology about 15 years ago. Hud established and directed the National Science Foundation-NASA Center for Chemical Evolution (CCE). The $20 million initiative set a goal of determining the identity and origins of the molecules that gave rise to life on Earth. The project wrapped up in 2021 after a decade of work that revealed plausible candidates for the first molecules and key chemical reactions of life.

Williams, a professor in the School of Chemistry and Biochemistry who chaired AbSciCon when Georgia Tech last hosted in 2012, reconstructs ancient ribosomes, the oldest assembly in biology. He served as director of the Center for Ribosomal Origins and Evolution, part of the NASA Astrobiology Institute from 2008 to 2015. Now he leads COOL: Georgia Tech's Center for the Origin of Life on Earth. COOL is supported by the NASA Astrobiology program.

Section cover art: NASA's Perseverance Mars rover is searching for signs of ancient microbial life and documenting the Martian landscape. Right: Jennifer Glass, Frank Rosenzweig, and Martha Grover (from left to right) represent Georgia Tech as chairs of AbSciCon 2022. CANDLER HOBBS



ART: SARAH COLLINS

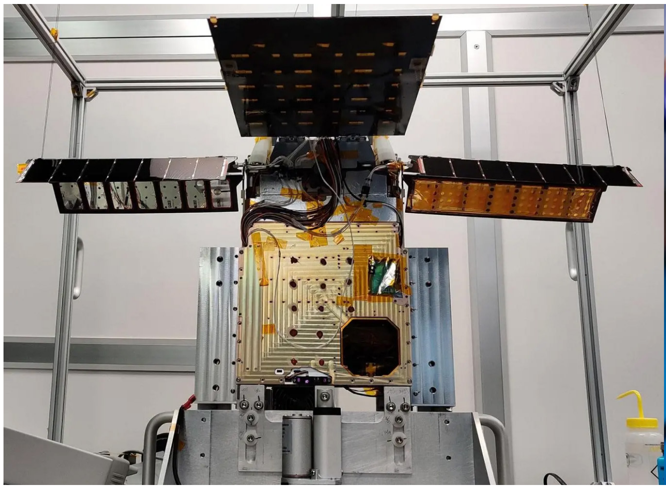
Georgia Tech's astrobiology community has evolved into additional research areas since Hud and Williams' early initiatives.

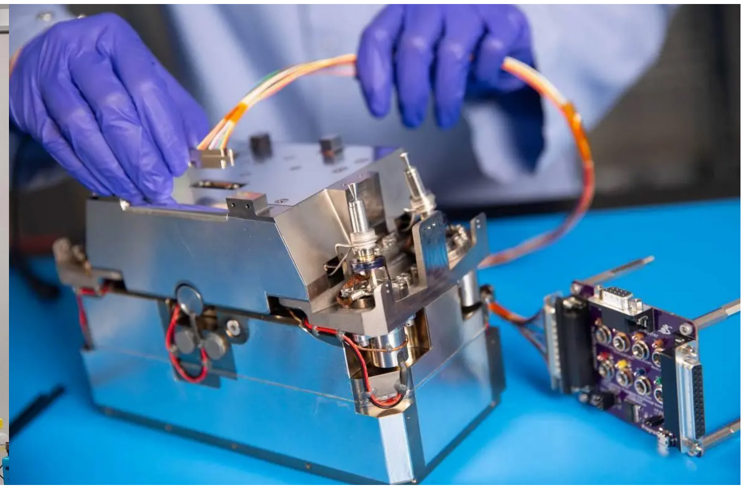
Professor **Frank Rosenzweig** was the science chair of AbSciCon 2022. His work in the School of Biological Sciences is focused on the evolution of complex traits that augment biodiversity and drive major transitions in the history of life. One such transition is the evolution of multicellular organisms like animals, plants, and fungi from single-celled ancestors.

"Each of these types of organisms appear to have originated from a single eukaryotic ancestor. However, multicellularity has originated independently dozens of times across the 'tree of life,' suggesting that diverse genetic and ecological mechanisms enable this transition to occur," Rosenzweig said. "In every case, the evolution of multicellularity has opened the door not only to large size organisms, but also to the evolution of cell types and a division of labor among them."

Other Georgia Tech faculty, including Associate Professor **Will Ratcliff** and Associate Professor **Peter Yunker**, are also carrying out research on the origins of multicellularity. Their teams have developed experimental systems to follow multicellularity as it evolves in real time in the laboratory, making it possible to elucidate its underlying genetic mechanisms, biophysics, and evolutionary advantages and disadvantages. Ph.D. students and postdocs from Ratcliff and Yunker's labs presented their latest research findings at AbSciCon.

Left: The cubesat after the solar array deployment test. Right: The Lunar Flashlight propulsion system developed by the Lightsey lab.
CONNER AWALD, CANDLER HOBBS





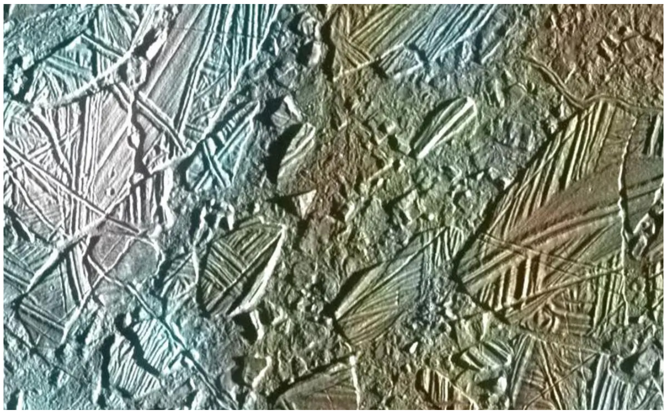
> *“We are especially proud of the numerous Georgia Tech students and postdocs in our Astrobiology Program and ExplOrigins student group who presented and convened sessions at AbSciCon.”*
>
> *Jennifer Glass, School of Earth and Atmospheric Sciences*

Others look for water beyond Earth. This year, a spacecraft assembled on campus is scheduled to launch from Florida and orbit the Moon. Lunar Flashlight will use powerful lasers and an onboard spectrometer to search shaded areas of craters at the south pole for evidence of surface ice. Its propulsion system was built by faculty, researchers, and students in the Daniel Guggenheim School of Aerospace Engineering. The AE School and the Georgia Tech Research Institute also assembled and tested the 30-pound CubeSat, which will be the first spacecraft to use active laser spectroscopy to explore the Moon’s surface.

A number of faculty are also looking for water far beyond our moon. **Glenn Lightsey** (AE School) and **Christopher Carr** (AE School and the School of Earth and Atmospheric Sciences: EAS) both worked on a potential mission, described at AbSciCon, that would put a vehicle on Jupiter’s Europa to look at that moon’s subsurface lake. **James Wray**, an associate professor in EAS, presented twice at the conference about potential life on both Europa and Mars.

EAS Associate Professor **Jennifer Glass** is the conference’s local organizing chair and co-director of the Georgia Tech Astrobiology Program. Her research focus is on the early evolution of life, including how methane and nitrous oxide played a role in warming the planet during its first 3.5 billion years. She also studies the habitability of gas-water hydrates on Earth and other planetary bodies. Using early-Earth knowledge, Glass and colleagues, including EAS Associate Professor **Chris Reinhard**, investigate the ways in which life could be evolving on billions of exoplanets spread throughout the universe.

“We are especially proud of the numerous Georgia Tech students and postdocs in our Astrobiology Program and ExplOrigins student group who presented and convened sessions at AbSciCon,” said Glass.



Scientists believe an ocean lies beneath the icy crust of Europa.
NASA/JPL/UNIVERSITY OF ARIZONA

AbSciCon attracted academics, NASA researchers, and astrobiologists from around the world to Atlanta. Among the more than 100 Georgia Tech researchers listed on abstracts is EAS Assistant Professor and Georgia Tech Astrobiology Program Co-Director **Frances Rivera-Hernández** (habitability on non-Earth terrains) and School of Physics Associate Professor **Gongjie Li** (possibility of life on exoplanets).

Former College of Sciences postdoctoral fellow **Betül Kaçar** was one of AbSciCon’s featured speakers. The assistant professor at the University of Wisconsin-Madison gave a conference-wide lecture on early evolution and molecular paleobiology.
• JASON MADERER

PHOTO: NASA

NASA Astrobiology Unveils New Research Coordination Network at AbSciCon

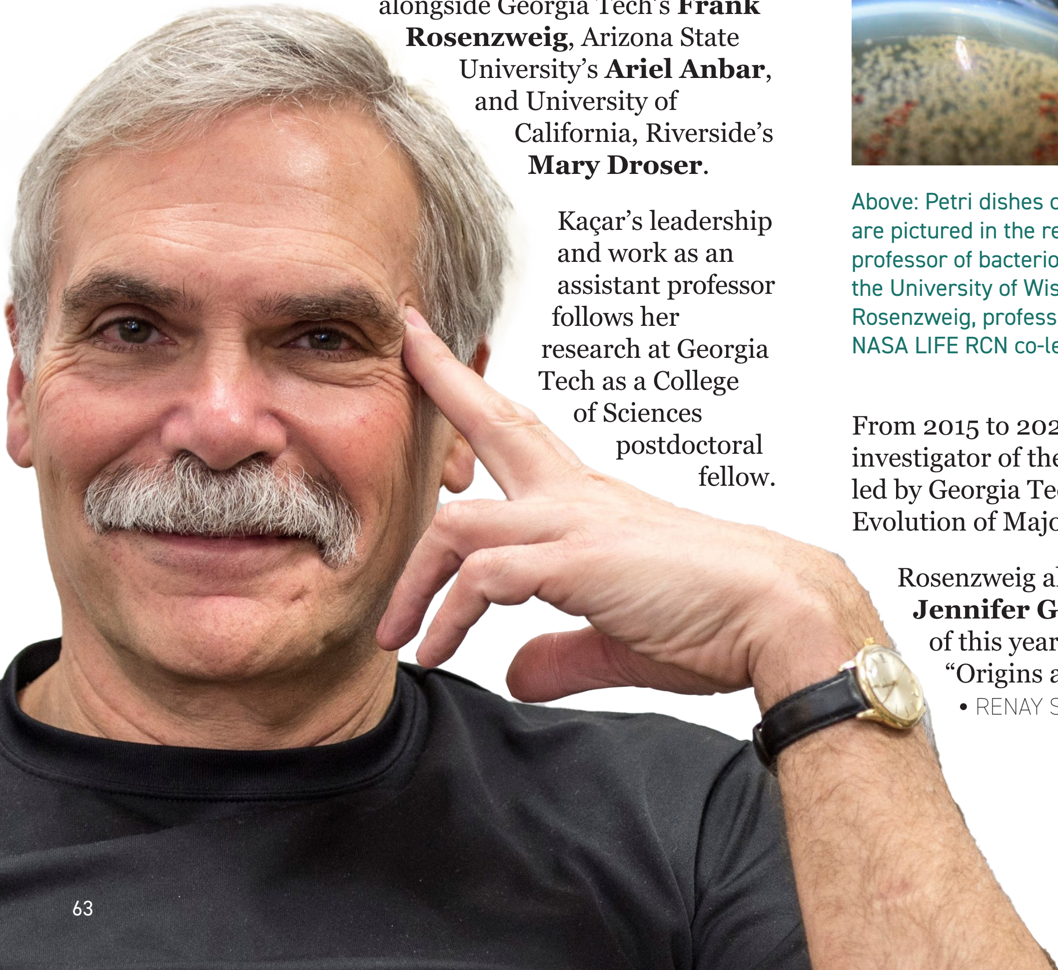
This past summer, NASA's Astrobiology program launched its newest Research Coordination Network (RCN), bringing together a collaboration of researchers from around the world who will spend the next five years investigating the earliest biological processes and the evolution of life into more complex organisms.

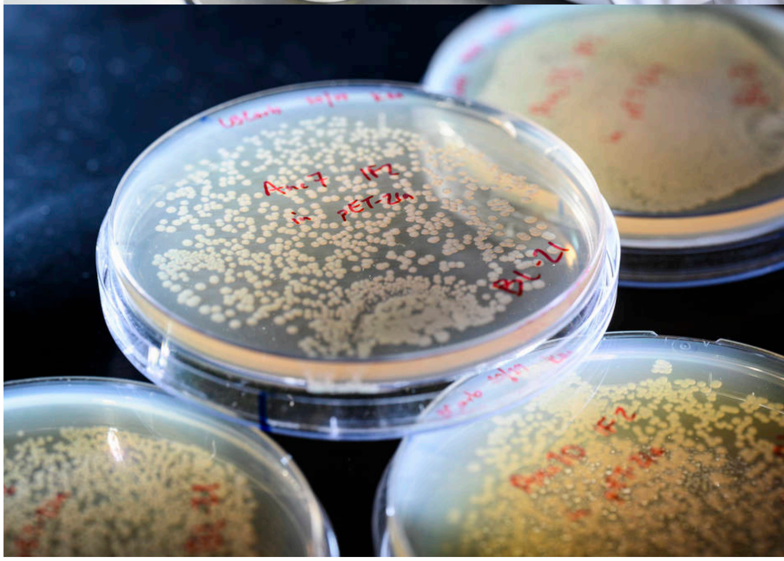
The new initiative, called "LIFE: Early Cells to Multicellularity," was officially launched at the 2022 Astrobiology Science Conference, hosted by Georgia Tech in May. The field of astrobiology seeks to understand how life originated and evolved on Earth so we can search for life elsewhere in the universe.

NASA's Research Coordination Networks are virtual collaboration structures designed to support groups of investigators to communicate and coordinate their research across disciplinary, organizational, divisional, and geographic boundaries.

The LIFE RCN is co-led by the University of Wisconsin–Madison's **Betül Kaçar** alongside Georgia Tech's **Frank Rosenzweig**, Arizona State University's **Ariel Anbar**, and University of California, Riverside's **Mary Droser**.

Kaçar's leadership and work as an assistant professor follows her research at Georgia Tech as a College of Sciences postdoctoral fellow.





Above: Petri dishes containing cultures of ancient DNA molecules are pictured in the research lab of Betül Kaçar, assistant professor of bacteriology, in the Microbial Sciences Building at the University of Wisconsin–Madison on Oct. 21, 2021. Left: Frank Rosenzweig, professor in the School of Biological Sciences and NASA LIFE RCN co-lead. NASA, JEFF MILLER

From 2015 to 2021, Rosenzweig served as principal investigator of the NASA Astrobiology Institute node led by Georgia Tech, "Reliving the Past: Experimental Evolution of Major Transitions in the History of Life."

Rosenzweig also recently joined fellow faculty **Jennifer Glass** and **Martha Grover** as chairs of this year's international AbSciCon, themed "Origins and Exploration: From Stars to Cells."

• RENAY SAN MIGUEL

One More Weapon in Cholera's Deadly Arsenal

Interdisciplinary researchers discover a new membrane-dissolving toxin, giving science a possible new direction for battling pathogens

V*ibrio cholerae*, the pathogenic bacterium that causes cholera, has killed millions worldwide, and is still found in countries where infrastructure doesn't support clean water. Cholera patients can suffer from severe vomiting and diarrhea, which can lead to fatal dehydration.

One factor *V. cholerae* uses to cause disease is a toxin-loaded "nano-harpoon," in the words of **Brian Hammer**, associate professor in the School of Biological Sciences. "Many pathogenic bacteria, including *V. cholerae*, are successful in the environment and human body because they compete for food and space by lancing their neighbors with that harpoon. The harpoon's toxic 'contact-antibiotics' kill bacteria from the inside. Thwarting human pathogens will require an understanding of these arsenals."

Hammer is on a team of scientists from Georgia Tech who have found a previously unknown weapon in the arsenal of cholera bacteria: a toxin that impairs a cell's membrane and looks like none described prior — hence the title of the team's research study: "A New Contact Killing Toxin Permeabilizes Cells and Belongs to a Broadly Distributed Protein Family," published in the scientific journal *mSphere*.

Team members included Hammer (the study's corresponding author), and Hammer Lab alumni **Christian Crisan** (the study's lead author), and **Catherine Everly**; along with Associate Professor **Peter Yunker** and Postdoctoral Scientist **Gabi Steinbach** of the School of Physics; and Professor **Raquel Lieberman** and Research Scientist **Shannon Hill** of the School of Chemistry and Biochemistry.

The technical term for *V. cholerae*'s "nano-harpoon" is a Type 6 Secretion System (T6SS). "While many microbiologists have focused their efforts on a few toxins made by *V. cholerae* obtained from patients, we sequenced the DNA of *Vibrios* from non-human environmental sources and developed computational tools to find new contact-antibiotic toxin genes," Hammer said. "In doing so, my [former Ph.D.] student Cristian Crisan discovered a new T6 toxin that doesn't look like any other protein characterized prior. He showed this toxin" — which the team named TpeV (type VI permeabilizing effector *Vibrio*) — "kills competitors by altering their cell membranes." Doing so results in cell damage or death.

Hunting through a database, Crisan discovered that hundreds of other bacteria, including pathogens like *Salmonella* and *Proteus*, also carry this novel toxin. "Our current work is studying exactly how this contact-antibiotic works, and ways that bacteria can adapt to become resistant to it and other T6 toxins," Hammer said.

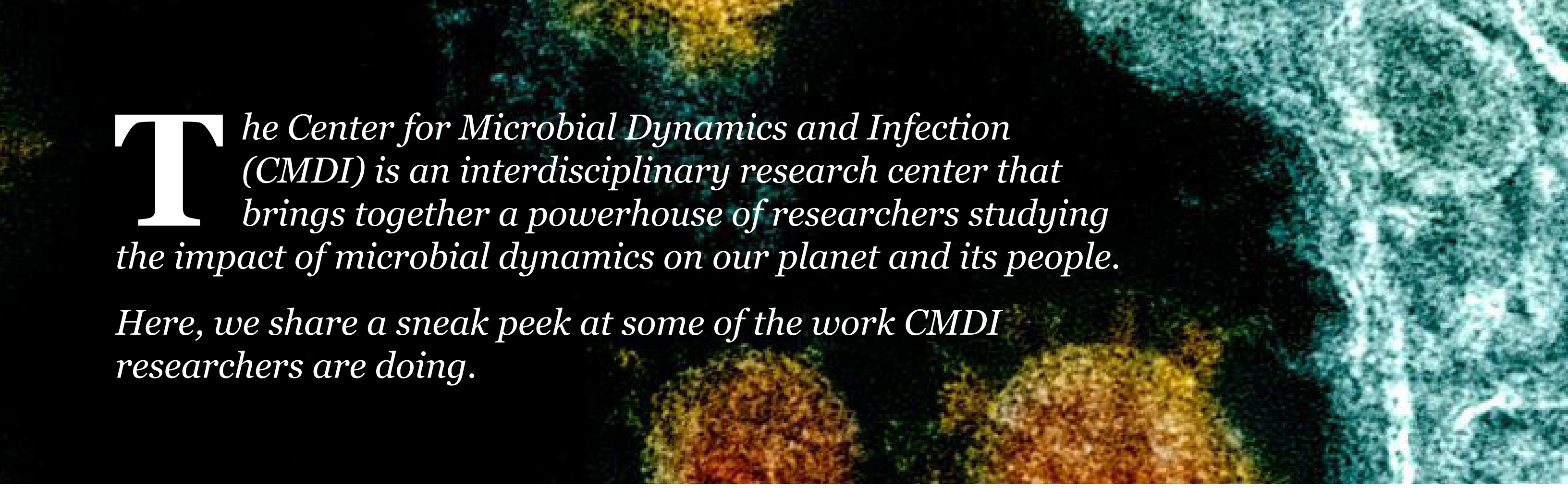
Cholera remains a well-studied disease since it touches many disciplines including microbiology, epidemiology, aquatic ecology, and water resource management, he added. Outbreaks still occur in places such as Bangladesh, Yemen, and Haiti. Learning more about *V. cholerae*'s toxins, and their antimicrobial abilities, could mean more effective ways to deal with antibiotic resistance, now an area of concern for microbiologists.

"We propose that TpeV-like toxins contribute to the fitness of many bacteria," the team wrote in its study. "Finally, since antibiotic resistance is a critical global health threat, the discovery of new antimicrobial mechanisms could lead to the development of new treatments against resistant strains." • RENAY SAN MIGUEL

The School of Biological Sciences, the National Science Foundation, the U.S.-Israel Binational Science Foundation, and the German National Academy of Natural Sciences Leopoldina contributed to this research study.

"Many pathogenic bacteria, including V. cholerae, are successful in the environment and human body because they compete for food and space by lancing their neighbors with that harpoon. The harpoon's toxic 'contact-antibiotics' kill bacteria from the inside. Thwarting human pathogens will require an understanding of these arsenals."

Brian Hammer, School of Biological Sciences



The Center for Microbial Dynamics and Infection (CMDI) is an interdisciplinary research center that brings together a powerhouse of researchers studying the impact of microbial dynamics on our planet and its people.

Here, we share a sneak peek at some of the work CMDI researchers are doing.

Mighty Microbial Dynamics for a Healthier People and Planet

Shaping the shared future of microbes and human health is the mission for Georgia Tech's Center for Microbial Dynamics and Infection (CMDI).

Yes, there are similar academic-based centers studying infectious diseases and the microbes that cause them, but to understand what makes Georgia Tech's center different, **Sam Brown**, CMDI director and a professor in the School of Biological Sciences, said to concentrate on that third letter in the Center's name.

"Focus on dynamics," said Brown. "That's basically how microbes are changing over time and space as well as how they're changing systems in time. This notion of dynamics operates on different scales. It operates, as I see it, on a behavioral scale — individual bugs making decisions and changing their behavior in time."

Ecological dynamics are "how populations are changing with time, and how they're interacting with other communities — for example in biofilms," Brown added, referring to communities of microorganisms that stick to surfaces and create their own "neighborhoods."

There are also evolutionary dynamics, which are worrying to Brown and other researchers, as they can mean bacteria increase resistance to antibiotics. And then there are epidemiological dynamics.

For over two years, we've all been "glued to our screens watching the epidemiological dynamics of Covid-19 play out in real time," he explained.

All of this involves the study of some of the natural world's tiniest troublemakers — and helpers. Humans are pathetically outnumbered by microbes. They live in, on, and around all of us. They are at both ends of the human food chain, helping farmers grow food, and then assisting us in digesting our meals.

"You have trillions of bacteria in your gut," points out **Marvin Whiteley**, CMDI's founding director who serves as a professor in the School of Biological Sciences, Georgia Tech Bennie H. and Nelson D. Abell Chair in Molecular and Cellular Biology, Georgia Research Alliance Eminent Scholar and co-director for Emory-Children's Cystic Fibrosis Center. So, in the spectrum of these tiny communities, there are helpful and harmful microbes alike — and the latter can often make us very sick.

That's where CMDI experts step in. "CMDI is working to transform how we study microbes in an environmental context, and ultimately find new microbial strategies to improve human and environmental health," Brown said.

CMDI's science is conducted in an interdisciplinary manner, like many other research centers at Georgia Tech, with research that reaches into a number of other disciplines — microbial ecology, microbiome dynamics, biogeochemistry, microbial biophysics, socio-microbiology, infection dynamics, host-pathogen interactions, marine and aquatic microbiology, microbial evolution, viral ecology, spatial imaging, and mathematical/computational modeling.

The Center is fairly new, beginning operations in 2018. Yet it's already closing in on 100 researchers — faculty, graduate students, and postdoctoral students — and is aggressively recruiting early career scientists from around the world to research at CMDI.

"We are a unique interdisciplinary research center since our expertise spans such broad subjects from coral reef ecosystems, to antibiotic resistant bacteria, to new infectious diseases therapies," explained **Maria Avdonina**, appointed CMDI manager through summer 2022. *More on the Center's work:*

Building CMDI's Foundation, and Using it to Attack *P. aeruginosa*

"How does a pathogen do what it does at the molecular level?" asked **Marvin Whiteley**, our founding director of CMDI.

It is a question that Whiteley began asking at The University of Texas at Austin, where he founded another center to study infectious disease before coming to Georgia Tech in 2017.

Back then, Whiteley was looking for the kind of interdisciplinary mix of researchers that can be found widely across the Institute, so he moved to Atlanta and built that into the CMDI's mission.

"It's the idea of not just working with pure microbiologists, but working with those interested in how things change, and their dynamic aspects, even daily changes in the microbiome," he said, referring to the term used to describe all the microorganisms that live in a particular environment, whether it's a human body or a body of land or water.

"It requires modelers — people used to looking at big data sets — and people who think about evolutionary biology," Whiteley added. "It's a unique kind of expertise that I don't have in my lab, but the folks who work for me in the lab can take advantage of it within CMDI."

Whiteley's research interests include the study of cystic fibrosis (CF), a genetic disease that results in bacteria chronically attacking the lungs of its patients. To combat disease, Whiteley is focusing research on *Pseudomonas aeruginosa* (*P. aeruginosa*), a particularly dangerous bacteria that's often found in CF patients' lungs. He noted that the Centers for Disease Control (CDC) lists it as one of the primary pathogens that is cause for clinical concern.

"It lives in nature, but we published a paper showing it's not everywhere. It's located near human activity, so wherever we are, it seems to grow and do really well. It's in a lot of different diseases — and CF is one of them."

P. aeruginosa is also "a really important cause of wound infections," Whiteley added, citing a CDC estimate that by 2050, about 20 percent of the entire U.S. healthcare budget could be spent treating chronic wound infections.

"The biggest problem in environments where it's problematic is hospitals," he said. "It's very tolerant of antimicrobials, and it acquires resistance fairly quickly. That causes it to enrich in its environment."

• RENAY SAN MIGUEL

CMDI's Joshua Weitz: Taking on Covid-19

Joshua Weitz, CMDI faculty member, professor and Tom and Marie Patton Chair in Biological Sciences, and founding director of the Interdisciplinary Ph.D. in Quantitative Biosciences (QBioS) program, is a key scientist behind Georgia Tech's Covid-19 surveillance testing efforts, along with Covid-19 event risk and population immunity modeling research around the nation and beyond.

Weitz has led a series of concurrent efforts to estimate epidemiological characteristics of SARS-CoV-2, develop novel approaches to use large-scale testing as an intervention, and leverage mathematical models and real-time datasets to inform the public of ongoing transmission risk.

Weitz recently received a best paper award from the Georgia Tech Chapter of Sigma Xi for his work on the Covid-19 Event Risk Assessment Planning Tool, which calculates the odds of being exposed to an infected individual in groups of different sizes; it has received more than 16 million unique visitors who have generated more than 60 million risk estimates since the planning tool's launch in July 2020.

Weitz also joined fellow faculty and staff in sharing an Institute Research Award and Institute Service Award in recognition of collective efforts to design, develop, implement, deploy an asymptomatic SARS-CoV-2 saliva-based testing program to address the coronavirus pandemic across campus. "We're very proud of what Joshua has done," said Sam Brown, "both in the context of Covid-19 and also in exploring new therapeutic angles for bacterial infections, by harnessing the viral natural enemies of bacteria: phages."

• RENAY SAN MIGUEL

The Search for New Antibiotics — and How Best to Use Them

While Covid-19 is a virus that has dominated headlines since early 2020, bacterial resistance to antibiotics has been a problem for decades. Penicillin was first available as an antibiotic in 1941. *Staphylococcus aureus* was found to be resistant to it as early as 1942.

CMDI faculty member **Julia Kubanek**, professor in the School of Biological Sciences and School of Chemistry and Biochemistry, former associate dean for Research in the College of Sciences, and current vice president for Interdisciplinary Research (VPIR) for Georgia Tech, has spent the past 17 years diving into the waters near Fiji and the Solomon Islands, looking for natural marine products that could fill that widening gap in resistance-free drugs.

"It's been a long time since entirely new classes of antibiotics were brought to market," Kubanek explained. "Pharmaceutical companies have reduced their investments in antibiotic drug discovery, despite the continuing rise of antimicrobial resistance among existing drugs. More resistant strains of infectious bacteria and fungi are evolving constantly and present severe threats to public health."

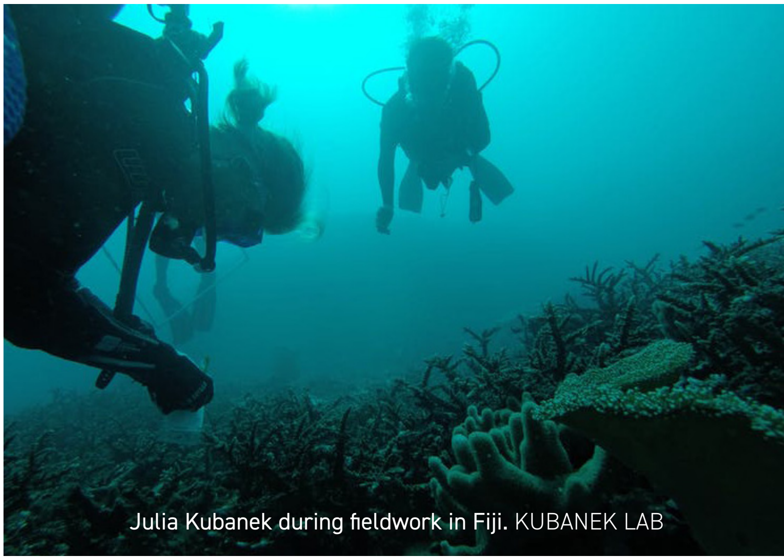
The Covid-19 pandemic is a related example. It has revealed that science's arsenal of antiviral drugs is inadequate, she noted.

Kubanek and CMDI faculty colleague **Mark Hay**, Regents' Professor and Harry and Linda Teasley Chair in the School of Biological Sciences, are both part of Georgia Tech's drug discovery program, which looks at small molecule natural products from marine organisms as sources for potential future medicines against infectious diseases.

A partnership with Emory University School of Medicine helps researchers screen Georgia Tech's natural product library — what Kubanek and her research team found on those South Pacific trips — for potential drug candidates, and has resulted in encouraging news for viruses like SARS-CoV-2, the specific coronavirus that causes Covid-19.

"We're currently following three promising classes of natural products from marine algae and sponges that show preliminary activity against this coronavirus," Kubanek said. Those molecules are distinct from currently marketed antivirals and antibiotics, and that could mean more weapons in science's arsenal for fighting infectious diseases.

CMDI researchers also approach the antibiotic resistance crisis through an epidemiological and evolutionary lens. For example, recent work from the Sam Brown Lab has identified new strategies to slow or even reverse the increase in drug-resistant strains, by changing how doctors dose their drugs, and how they make use of diagnostic information. • RENAY SAN MIGUEL



Julia Kubanek during fieldwork in Fiji. KUBANEK LAB

Microbes, Climate, and Environmental Health

Beyond human infections and pathogen control, CMDI also focuses on the significant impacts that microbes have on human and environmental health. CMDI faculty member **Joel Kostka**, professor and associate chair of Research in the School of Biological Sciences who also serves as a professor in the School of Earth and Atmospheric Sciences, is a leading researcher in environmental microbiology, bringing the power of "omics" technologies to discover the role of environmental microbes in shaping key aspects of our shared world, from bioremediation to climate change.

Kostka's work led to the discovery of key marine microbes that played an important role in cleaning up the oil spilled during the 2010 Deepwater Horizon disaster — microbes that turned out to be abundant in oil-contaminated soils around the world.

The work "revealed a natural capacity for rare microbes in the Gulf of Mexico to catalyze the bioremediation, or natural cleanup, of petroleum hydrocarbons," he said. "These microbes show promise as biological indicators to direct emergency response efforts, as well as to elucidate the impacts of oil exposure on ecosystem health during oil spills and other environmental disasters." The Kostka Lab has also long characterized the role of the environment in shaping microbial communities that limit the release of greenhouse gases like carbon dioxide and methane into the atmosphere.

In a large scale climate change experiment that's being conducted in northern Minnesota with funding by the U.S. Department of Energy, Kostka's research recently showed that warming accelerates the production of greenhouse gases from soil microbial respiration — and that microbial activity "was fueled by the release of plant metabolites, suggesting that enhanced greenhouse gas production is likely to persist and result in amplified climate feedbacks."

"Joel is our key player in this space," said **Sam Brown**, CMDI director. "He's done incredible research on how the environment can dictate microbial species abundance and their behavioral contributions to the functioning of Earth's ecosystems. He's shown that different 'taxa', or groups of organisms, become metabolically active or 'switched on' depending on environmental factors like temperature. His research contributes to building better climate models as well as to develop new geoengineering strategies to adapt to climate change. He's doing beautiful work."

• RENAY SAN MIGUEL

Joel Kostka (fourth from left) with members of his lab. JOEL KOSTKA LAB

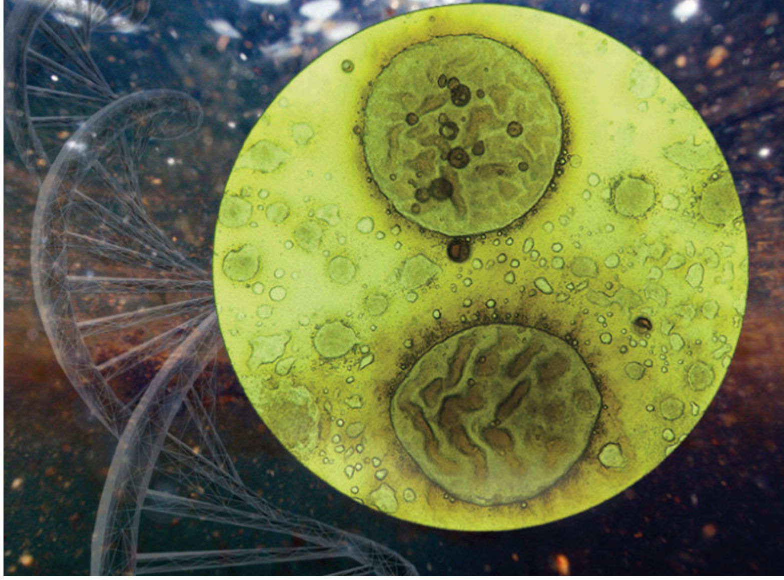
CMDI's Global Call to Early Career Microbiologists

CMDI's research is funded by grants from agencies like the National Science Foundation and National Institutes of Health to individual labs run by faculty — and by money distributed directly to the Center from across Georgia Tech, including the College of Sciences and its Office of the Dean and Sutherland Dean's Chair.

These sources "are getting healthier by the minute, and that's a testament to the scientists at the Center," **Sam Brown**, the CMDI director, points out — so much so that two new positions have recently been created: a senior research scientist who will assist postdoctoral and graduate students with grant and fellowship applications, and a CMDI Early Career Award Fellowship that seeks out "superstars, people who are going to go on to be faculty success stories."

"We want to get them early," Brown said. "We're interviewing some great candidates just out of their Ph.D.s. We'll give them maximum independence, their own space, their own office, their own pot of money. They'll be sitting at the intersection of our research interests but can run their own lab and their own research program."

This allows postdoctoral students to focus on research projects, CMDI faculty member **Julia Kubanek** said. "Because postdocs generally don't enroll in formal courses, nor are they generally expected to teach in the classroom, they get to immerse themselves in research in collaboration with faculty, students, and other postdocs. The CMDI is rapidly growing as a collaborative environment, where postdocs can try out their best ideas and learn from others how to tackle the most pressing scientific questions in microbial dynamics, microbial communication, ecosystem health, and infectious disease." Kubanek added that a related fellowship program "will augment postdoctoral salaries to attract the very best candidates, enabling grant dollars to stretch further, leading to new discoveries."



Composite of oil droplets and microbes from the Deepwater Horizon spill. COURTESY AP IMAGES/SHUTTERSTOCK/SHMRUTI KARTHIKEYAN/EOS MAGAZINE

"Our trainees get practice in speaking, and it opens doors to folks seeing Georgia Tech as an option," Brown explained. The CMDI is also working with Georgia Tech's Institute Diversity, Equity, and Inclusion and the Southern Regional Education Board to continue to increase the number of underrepresented minorities at all levels of recruitment.

"We're really interested in educating the next generation of scientists in biology," added CMDI's founding director **Marvin Whiteley**. "Everybody says that — but we're actually developing programs to recruit the best talent in the world." • RENAY SAN MIGUEL

"We're really interested in educating the next generation of scientists in biology ... we're actually developing programs to recruit the best talent in the world."

Marvin Whiteley, CMDI's founding director

Samuel (Sam) Brown, professor and CMDI director.

The Center for Microbial Dynamics and Infection's inaugural Early Career Award Fellow shares about launching her interdisciplinary postdoctoral research program and asks: Can a bacteria that's "good at scooping up DNA" teach us about harnessing viruses to battle bacterial infections?

No Separations: Meet Ellinor Alseth, CMDI's First Early Career Award Fellow

Ellinor Alseth works on the bacteria *Acinetobacter baumannii* mainly because she's curious about its unusual evolution and ecology, but also because it's an important pathogen.

"I've always thought that it would be nice if you can answer clinically relevant questions and more broadly evolutionary ones at the same time. Maybe I'm just very ambitious, but I don't see why those two things always have to be so separated," she said. Research funding is often siloed to answer either medical or basic research questions, less often both on a single project.

Alseth is in the right place to be ambitious. She started this March as the first Early Career Award Fellow at the Center for Microbial Dynamics and Infection (CMDI) at Georgia Tech, which prides itself on building connections across disciplines. Its 12 participating labs hail from three schools in the College of Sciences: Biological Sciences, Physics, and Chemistry and Biochemistry. They share a common research focus on the role of microbes like bacteria and viruses in human and environmental health.

The fellowship will fund Alseth and her research for three years. "There's nothing like this on campus, to my knowledge," said Sam Brown, CMDI's director.

The most important aspect of the fellowship, he said, is independence: "It's unusual to be able to put junior scientists truly in the driver's seat with their research agenda, especially at the junior postdoc level. We have a panel of mentors that offer support, but not instruction."

That promise of independence was a major pull for Alseth, who moved from Europe to Atlanta for the fellowship. She's from Norway and completed her Ph.D. at the University of Exeter in the United Kingdom, and cited the chance to do interdisciplinary microbial research at CMDI as a primary reason she decided to make the move.

"It's nice to complement my evolutionary and ecology skills with molecular work, because that's where I feel like I have the biggest gap in knowledge," Alseth said. Studying molecules (such as chemical signals between bacteria) requires quite a different set of skills than ecology and evolution. "And CMDI has everything you could possibly dream of for answering fairly complicated molecular questions."

"There's nothing like this on campus, to my knowledge ... It's unusual to be able to put junior scientists truly in the driver's seat with their research agenda, especially at the junior postdoc level."

Sam Brown, CMDI and School of Biological Sciences

Alseth's research at CMDI will focus on phage therapy, combining approaches and ideas from community ecology, evolutionary biology, and molecular biology. Phages are viruses adapted to infect bacteria, and they are harmless to humans. That means they can serve as alternative or supplemental treatments to antibiotics, *"I've always thought that it would be nice if you can answer clinically relevant questions and more broadly evolutionary ones at the same time. Maybe I'm just very ambitious, but I don't see why those two things always have to be so separated."*

Ellinor Alseth, CMDI

with fewer side effects. Many bacteria have evolved to escape and resist antibiotics, leading to a major global public health threat expected to worsen in the decades ahead. Phage therapy is one possible solution in an arsenal of tools, but it is not nearly as well-understood as therapeutic drugs.

Phage therapy is typically a last-ditch therapy after antibiotics have failed. However, fighting biology with biology is complex and may have unintended consequences. "Phage therapy is the concept that 'the enemy of my enemy is my friend,'" Alseth said. "But as an evolutionary biologist, I want to know what the consequences might be. How will the bacteria respond? The worst-case scenario is that [scientists] will do what we did with antibiotics and go in blind, thinking we have a solution that will last forever."

So, Alseth is working with the bacteria *Acinetobacter baumannii* to understand how it evolves to resist phages. *A. baumannii* is one of the so-called 'ESKAPE' pathogens, an acronym of the names of six bacteria that are resistant to many antibiotics and commonly spread in hospital settings.

A. baumannii is interesting to Alseth because "It's very good at scooping up DNA from its environment," which helps it evolve to escape antibiotics by picking up genes from other microbes around them. In hospitals and in the human body, *A. baumannii* may be surrounded by other bacteria. Each species is evolving new strategies to escape its phage, and *A. baumannii* might be able to develop a formidable defense strategy by combining them all.

Ellinor Alseth, CMDI Early Career Award Fellow.

Alseth's Ph.D. research, published in the journal *Nature*, found that growing multiple microbe species together affected the course of phage resistance evolution in the more commonly studied bacteria *Pseudomonas aeruginosa*. Although *Pseudomonas* is studied by several labs in CMDI, for her postdoctoral studies Alseth chose to switch to *A. baumannii*, a species that she found had strong effects on evolution of other bacteria. Alseth noticed there was very little known about its evolution and ecology. "I realized that there is a gap here that I was quite curious about," she said.

That interdisciplinary curiosity was important to the fellowship selection committee, said Brown, the CMDI director. Another reason Alseth was a good fit was her impactful research: "science that would change the way other people were doing science," as he put it. "This is a great way to bring the brightest talent to Georgia Tech, because we're offering an unprecedented deal in terms of the fellow's ability to lead their own science, and that's really valuable."

"Looking to donors, the hope is that we can extend our funding, and really expand this to have a cohort [of fellows]," Brown added, which would continue to boost the research agenda and profile of CMDI, College of Sciences, and Georgia Tech. "We hope and expect this is the launching pad for really bright careers."
• CARINA BASKETT

The CMDI Early Career Award Fellowship is supported by CMDI faculty funding.

Changing Genes

Gene network changes associated with cancer onset and progression identify new candidates for targeted gene therapy

Cancer chemotherapy has undergone a paradigm shift in recent years with traditional treatments like broad-spectrum cytotoxic agents being complemented or replaced by drugs that target specific genes believed to drive the onset and progression of the disease.

This more personalized approach to chemotherapy became possible when genomic profiling of individual patient tumors led researchers to identify specific "cancer driver genes" that, when mutated or abnormally expressed, led to the onset and development of cancer.

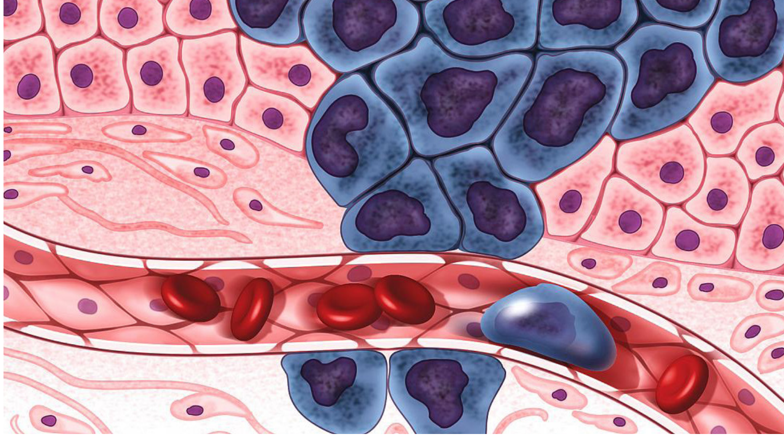
Different types of cancer — like lung cancer versus breast cancer — and, to some extent, different patients diagnosed with the same cancer type — show variations in the cancer driver genes believed to be responsible for disease onset and progression. "For example, the therapeutic drug Herceptin is commonly used to treat breast cancer patients when its target gene, HER-2, is found to be over-expressed," said **John F. McDonald**, professor in the School of Biological Sciences.

McDonald explained that, currently, the identification of potential targets for gene therapy relies almost exclusively on genomic analyses of tumors that identify cancer driver genes that are significantly over-expressed.

But in their latest study, McDonald and Bioinformatics Ph.D. student **Zainab Arshad** have found that another important class of genetic changes may be happening in places where scientists don't normally look: the network of gene-gene interactions associated with cancer onset and progression.

"Genes and the proteins they encode do not operate in isolation from one another," McDonald said. "Rather, they communicate with one another in a highly integrated network of interactions."

"What I think is most remarkable about our findings is that the vast majority of changes — more than 90 percent — in the network of interactions accompanying cancer are not associated with genes displaying changes in their expression," added Arshad, co-author of the paper. "What this means is that genes playing a central role in bringing about changes in network structure associated with cancer — the 'hub genes' — may be important new targets for gene therapy that can go undetected by gene expression analyses."



Growing cancer cells (purple) are surrounded by healthy cells (pink), illustrating a primary tumor spreading to other parts of the body via the circulatory system. DARRYL LEJA, NHGRI

Their research paper "Changes in gene-gene interactions associated with cancer onset and progression are largely independent of changes in gene expression" was recently published in the journal *iScience*.

Mutations, expression — and changes in network structure

In the study, Arshad and McDonald worked with samples of brain, thyroid, breast, lung adenocarcinoma, lung squamous cell carcinoma, skin, kidney, ovarian, and acute myeloid leukemia cancers — and they noticed differences in cell network structure for each of these cancers as they progressed from early to later stages.

When early-stage cancers developed and stayed confined to their body tissue of origin, they noted a reduction in network complexity relative to normal pre-cursor cells. Normal, healthy cells are highly differentiated, but as they transition to cancer, "they go through a process of de-differentiation to a more primitive or stem cell-like state. It's known from developmental biology that as cells transition from early embryonic stem cells to highly specialized fully differentiated cells, network complexity increases. What we see in the transition from normal to early-stage cancers is a reversal of this process," McDonald explained.

McDonald said as the cancers progress to advanced stages, when they can spread or metastasize to other parts of the body, "we observe re-establishment of high levels of network complexity, but the genes comprising the complex networks associated with advanced cancers are quite different from those comprising the complex networks associated with the precursor normal tissues."

"As cancers evolve in function, they are typically associated with changes in DNA structure, and/or with changes in the RNA expression of cancer driver genes. Our results indicate that there's an important third class of changes going on — changes in gene interactions — and many of these changes are not detectable if all you're looking for are changes in gene expression."

• RENAY SAN MIGUEL

New Grants Could Transform Scientists' Understanding of DNA

Two charitable foundations have announced their support of research at Georgia Tech that could change the basic understanding of DNA, potentially leading to new treatments for degenerative diseases.

The W.M. Keck Foundation and the G. Harold and Leila Y. Mathers Foundation have awarded grants of $1 million and $300,000, respectively, to boost the research of **Francesca Storici**, professor in the School of Biological Sciences and principal investigator for the projects. Both grants are directed toward decrypting the hidden message of ribonucleotide incorporation in human nuclear DNA.

"We have a lot to learn about the role ribonucleotides play in the structure and function of human DNA," said Storici, also a researcher with the Petit Institute for Bioengineering and Bioscience at Georgia Tech, whose lab already has contributed much to what the world knows about ribonucleotides, or rNMPs – the basic building blocks of RNA – when they are embedded in DNA.

Francesca Storici (left) and Natasha Jonoska.

Storici and her collaborators, including **Natasha Jonoska**, professor of mathematics at the University of South Florida, have developed new tools and techniques to find and characterize rNMPs in DNA. Their studies of yeast DNA suggest that rNMPs aren't just random "noise," as had been previously alleged, but rather offer a code — Storici and her colleagues call it "cryptic language" — capable of regulating DNA functions. The grants will help researchers begin to translate that cryptic language. • JERRY GRILLO

Peng Qiu (left) and Joshua Weitz are leading the National Institutes of Heath-funded training program, with the goal of transforming the study of quantitative- and data-intensive biosciences at Georgia Tech. ALLISON CARTER

3-2-1, InQuBATE

T32 training takes off with three graduate students

Three Ph.D. students — two from the College of Sciences — have been announced as the inaugural cohort for a new Georgia Tech training program designed to give biomedical researchers a deeper dive into quantitative, data-intensive studies.

The trio of students are part of a new five-year, $1.27 million grant from the National Institutes of Health (NIH) that creates the InQuBATE program to help transform the study of quantitative- and data-intensive biosciences at Georgia Tech. InQuBATE is designed to train a new generation of biomedical researchers and thought leaders to harness the data revolution.

"We want to improve and enhance the training of students to focus on biological questions while leveraging modern tools, and in some cases developing new tools, to address foundational challenges at scales from molecules to systems," noted **Joshua Weitz**, professor and Tom and Marie Patton Chair in the School of Biological Sciences, in the grant's announcement.

Weitz is co-leading the program with **Peng Qiu**, associate professor in the Wallace H. Coulter Department of Biomedical Engineering at Georgia Tech and Emory University.

Biology is undergoing a transformation, added Weitz and Qiu, requiring a new educational paradigm that integrates quantitative approaches like computational modeling and data analytics into the experimental study of living systems.

"Our intention is to develop a training environment that instills a quantitative, data-driven mindset, integrating quantitative and data science methods into all aspects of the life science training pipeline," said Weitz, who is also founding director of Tech's Interdisciplinary Graduate Program in Quantitative Biosciences (QBioS).

Meet the inaugural InQuBATE cohort

Kathryn (Katie) Wendorf MacGillivray: Quantitative Biosciences Interdisciplinary Graduate Program (advised by **Will Ratcliff**)

Katie Wendorf MacGillivray received a Master's in Biology from New York University where she worked on phenotypic heterogeneity of antibiotic susceptibility in the lab of Edo Kussell. She is now a Ph.D. student in the Quantitative Biosciences program at Georgia Tech. In the Ratcliff Lab, she is interested in engineering yeast that can switch between life cycles – unicellular, clonal, and aggregative. "I have a biology and chemistry background, and believe strongly that all biosciences research could benefit from the addition of computational modeling and/or data science approaches. That's why I chose QBioS for my Ph.D. program in the first place," she said.

Gabriella Chebli: Biological Sciences (advised by **Julia Kubanek**)

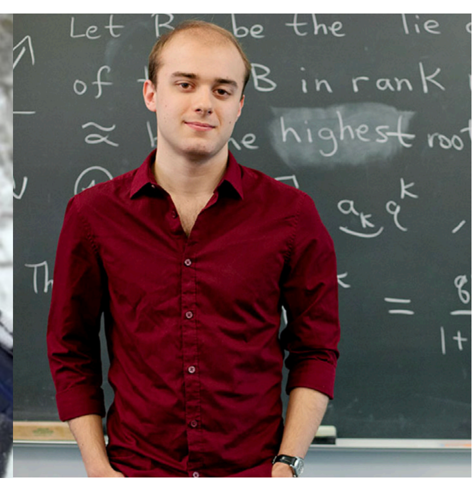
Gabriella Chebli graduated from Agnes Scott College with a Bachelor of Science in Biology and Chemistry. While an undergraduate, she conducted research under the direction of Chemistry professor Thomas Morgan to revise the structure of a class of natural products called "hyloins" that are found in the frog species Boana punctata. *Chebli also worked in the lab of Biology professor, Iris Levin, studying telomere length in adult barn swallows. In the Kubanek Lab, Chebli is researching chemical ecology and assisting with an algal biofuel ponds project and maintenance of phytoplankton cultures.*

Maxfield (Max) Comstock: Computational Science and Engineering (advised by **Elizabeth Cherry**)

Max Comstock, originally from Seattle, Washington, received his undergraduate degrees in Math and Computer Science from Harvey Mudd College. "I'm honored to be part of the inaugural InQuBATE cohort, and am looking forward to working with all the amazing people involved with the program," he said. "I hope to gain experience collaborating with researchers from different backgrounds who may approach problems from a different perspective, and to learn new ways to apply computational techniques to important biomedical problems. I intend to continue tackling medical problems using these skills throughout the rest of my career." • RENAY SAN MIGUEL

The inaugural InQuBATE cohort (from left): Katie MacGillivray, Gabriella Chebli, and Max Comstock.





Oxidants Vs. Antioxidants

Learning how the body fights off cellular damage

Because humans and animals breathe and metabolize oxygen, they generate a variety of reactive oxygen species (ROS), or cell-damaging oxidants, as byproducts. Our bodies usually make enough antioxidants to counter that damage, but when that balance starts to favor oxidants, they can attack important biomolecules like proteins, nucleic acids, and lipids. That can lead to cancer, neurodegenerative disorders, and cardiovascular diseases.

Fortunately, our bodies evolved to produce antioxidant enzymes such as Cu/Zn (copper/zinc) superoxide dismutase, or SOD1, which detoxifies certain harmful oxidants. In a weird twist, SOD1 is the only antioxidant enzyme that can take on one specific oxidant, superoxide, only to produce another ROS: hydrogen peroxide.

A team of Georgia Tech researchers have published a study that found an even stranger twist to this oxidant-antioxidant tale: SOD1 (good for cells) produces hydrogen peroxide (bad for cells) which stimulates the production of another important cellular antioxidant known as NADPH (also good for cells; more on this in a moment).

"Yes, you heard that right," said **Amit Reddi**, associate professor in the School of Chemistry and Biochemistry. "SOD1, an antioxidant enzyme, produces an oxidant, hydrogen peroxide, which in turn stimulates the production of another (good) antioxidant."

Reddi is a co-author of this research along with **Matthew Torres**, associate professor in the School of Biological Sciences; **Claudia Montllor-Albalate**, former Reddi Lab member who received her Ph.D. in 2020 from the School of Chemistry and Biochemistry; **Hyojung Kim**, School of Chemistry and Biochemistry Ph.D. candidate; **Annalise Thompson**, a third-year graduate student in Reddi's lab; and **Alex Jonke**, research scientist with the School of Biological Sciences.

Their study, "SOD1 Integrates Oxygen Availability to Redox Regulate NADPH Production and the Thiol Redoxome" is published in the *Proceedings of the National Academy of Sciences*.

> ***"Given the very collaborative and collegial nature of faculty across the College of Sciences, and the Institute as a whole, it was easy to grab a coffee and discuss these ideas."***
>
> *Amit Reddi, School of Chemistry and Biochemistry*

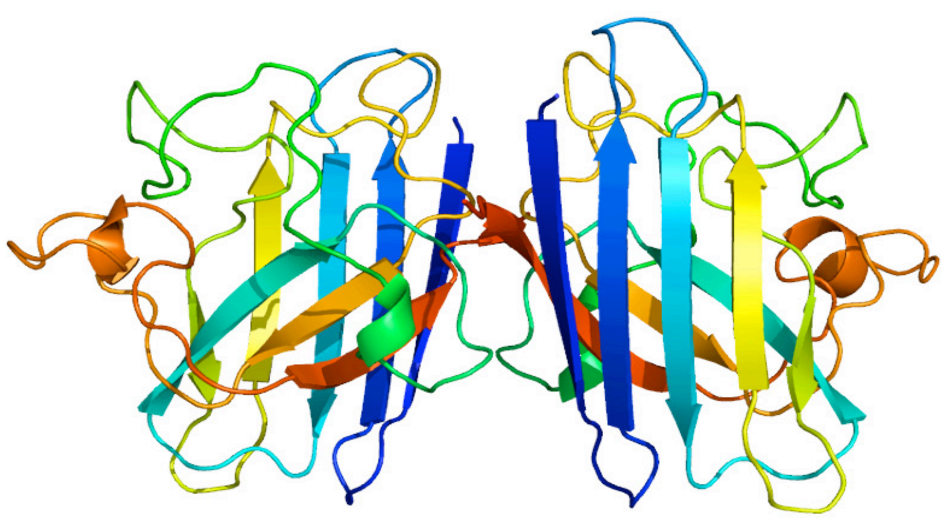
The story behind the SOD1 revelation

The PNAS research study began with a casual conversation in 2014 between Reddi and Torres at a café in the Parker H. Petit Institute for Bioengineering and Biosciences (IBB).

"Given the very collaborative and collegial nature of faculty across the College of Sciences, and the Institute as a whole, it was easy to grab a coffee and discuss these ideas," Reddi said. Work in the Reddi lab includes potential signaling roles for SOD1 and the hydrogen peroxide it produces; but understanding the extent to which these factors regulate signaling required a systems-level understanding of how widespread targets of SOD1 are in a cell.

Torres focuses on mass spectrometry-based proteomics (the study of all proteins produced and modified by an organism or system) to probe cell-wide signaling networks, so it seemed to Reddi like a perfect fit.

A look at the structure of the SOD1 protein.
BASED ON PYMOL.ORG RENDERING OF PDB 1AZV



Then, Reddi said, Montllor-Albalate made the discovery that SOD1-derived hydrogen peroxide can regulate NADPH production and adaptation to aerobic life. Meanwhile, Kim, a joint student of the Reddi and Torres labs, drove the work to identify proteome-wide targets of SOD1-derived hydrogen peroxide.

The conversation in IBB led to a 2016 grant from the National Institutes of Health to study the topic further. The resulting paper "we feel will make a strong impact in the field of redox biology and signaling," Reddi said.

Amit Reddi (left) and Matthew Torres.

SOD1's potential in future cancer therapy

SOD1 is often thought of as an appealing anti-cancer therapeutic because of its ability to scavenge superoxides. The theory is that if SOD1 is inactivated, cancer cells will be at a disadvantage.

Torres and Reddi are continuing their collaboration to investigate other aspects of SOD1 and hydrogen peroxide signaling in cancer metabolism and its implications for disease progression. • RENAY SAN MIGUEL

Research supported by the NIH and the Blanchard Fellowship at Georgia Tech.

Georgia Tech Selected as NIH Cell Characterization Hub

Georgia Tech has been selected as the in-depth cell characterization platform hub for the National Institutes of Health's (NIH) Regenerative Medicine Innovation Project (RMIP). Established under the 21st Century Cures Act, the main goal of the $30 million RMIP is the development of transformative new therapies based on adult stem cells.

"Our analysis will provide researchers a deeper understanding of the cell products in these various clinical and IND-supporting pre-clinical trials – the characteristics that contribute to their safety and efficacy, for example," said **Krishnendu Roy**, principal investigator of the new in-depth cell characterization (IDCC) Platform Hub. Through this kind of in-depth analysis of every cell therapy that is manufactured or used in an RMIP project, researchers will create what Roy and others call a "cell fingerprint."

"When we have created a large enough database, scientists will be able to correlate the cell fingerprint with the outcomes of a particular disease in a particular patient and gain insights into the critical quality attributes of the cells that make them most effective for a specific patient," said Roy, who serves as Robert A. Milton Endowed Chair and professor in the Coulter Department of Biomedical Engineering.

The IDCC Platform Hub will benefit from the existing resources at Georgia Tech, which include the Marcus Center for Therapeutic Cell Characterization and Manufacturing (MC3M), and the NSF Engineering Research Center (ERC) for Cell Manufacturing Technologies (CMaT).

Roy and **Carolyn Yeago**, associate director of the Marcus Center, will manage activities for the IDCC Platform Hub at Georgia Tech. The rest of the leadership team includes co-principal investigators **Andrés García**, executive director of the Petit Institute and Regents' Professor in the Woodruff School of Mechanical Engineering; **Greg Gibson**, director of the Center for Integrative Genomics and Tom and Marie Patton Chair in the School of Biological Sciences; **Facundo Fernández,** Regents' Professor and associate chair for Research in the School of Chemistry and Biochemistry; and **Craig Forest**, professor in the Woodruff School. • JERRY GRILLO

Surveillance Testing Shown to Reduce Community Covid-19 Spread

Covid-19 is often asymptomatic and can lead infected individuals to spread the disease without knowing it. Yet, regular surveillance testing of a community can catch these cases and prevent outbreaks.

In early 2020, Georgia Tech researchers designed a saliva-based polymerase chain reaction (PCR) test and encouraged community members to test weekly to track the health of the campus. Their strategy confirmed 62 percent of the campus' positive cases in the Fall 2020 semester. The method of surveillance testing — focusing on case clusters and then having patients isolate — reduced positivity rates from 4.1 percent in the beginning of the semester to below 0.5 percent mid-semester. Their findings were published in the journal *Epidemiology*.

"One of the ways you can mitigate spread is not to think about testing as just an indicator for how bad things are, but actually use enough testing that you can begin to pull infected people out of circulation to reduce the spread," said **Joshua Weitz**, Georgia Tech professor in the School of Biological Sciences who developed the infectious disease models used to monitor campus.

Surveillance testing not only kept the community safe, but also enabled an open campus during a period of the pandemic when vaccines were not available. The strategy showed that combining multiple mitigation efforts — from testing to social distancing — can keep a university operational.

Designing the test

Saliva-based tests were a practical solution for a campus. The test could be self-administered, requiring fewer medical personnel and creating ease of access for students.

"I saw data very early on that the saliva tests were actually probably a little bit more sensitive than the nasal ones," said **Greg Gibson**, professor in the School of Biological Sciences.

The Georgia Tech campus biomedical research labs were also ideal for this type of test. **Andrés García**, executive director of the Parker H. Petit Institute for Bioengineering and Bioscience, realized robotics labs could build and run tests and make the program scalable.

Lab technicians process inactivated saliva samples in the Covid-19 Surveillance Testing Lab at Georgia Tech.

From left to right: Andrés García, Greg Gibson, Joshua Weitz.

“Testing requires precisely distributing different amounts of fluid to volumes, and this is a task really well suited for a robot,” García said. “With the large number of tests that we were expecting to need to administer, there was really no choice because having the robot really cut down on the human error.”

The testing strategy

Creating an effective testing infrastructure was also key to the success of the program. A university is a high-density environment where a community lives, learns, and works. When the program was first implemented in the Fall 2020 semester, Georgia Tech had 7,370 people in residence and 5,000 students, faculty, and staff who visited daily.

With the ability to run 1,500 tests at the beginning of the semester and up to 2,850 by the end, the program enabled most people on campus to test weekly. Testing weekly helped catch cases early with Covid-19’s seven-day incubation period, and positive individuals isolated for 10 days.

Part of why this approach was so successful was because of what Gibson called “synergistic effectiveness.” By combining testing with mitigation strategies like masking and social distancing, Georgia Tech was able to reduce positivity rates.

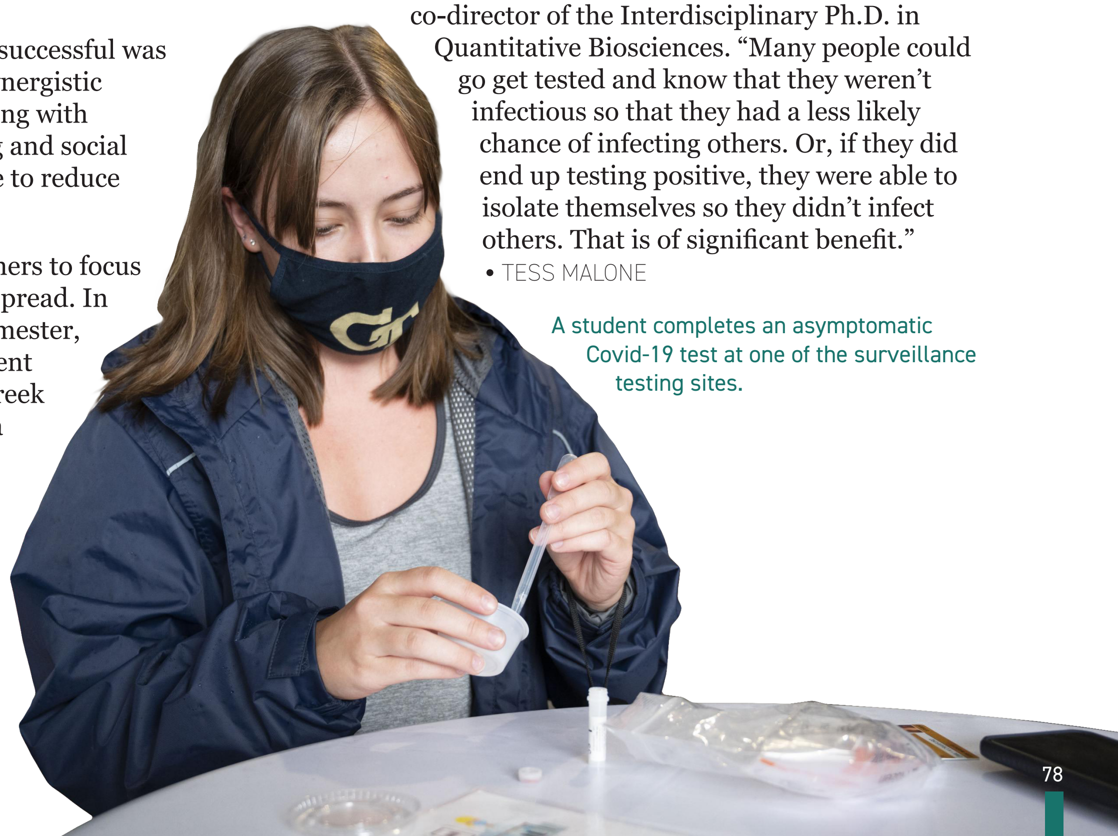
This strategy enabled the researchers to focus on campus hotspots and control spread. In the beginning of the Fall 2020 semester, campus positivity was at 0.5 percent until a cluster was identified in Greek housing in August. This enabled a targeted campaign where 90% of on-campus residents were tested. The asymptomatic positivity rate peaked at 4.1%, but steadily declined back to 0.5% by mid-September thanks to rapid identification and isolation of positive individuals.

“We are a technical university — that doesn’t have a medical school or a school of public health — that developed its own effective testing program and was able to deploy it to test a large segment of the population and keep the campus in operation,” said García.

Due to the success of surveillance testing, cases were kept at a manageable number. Most importantly, campus was able to stay open throughout the pandemic. The Georgia state legislature also adopted Georgia Tech’s surveillance testing system in January 2021 and used the program to track and manage cases during the year’s legislative session. The strategy has kept Georgia Tech an active campus with safe in-person learning as the pandemic evolves. Ideally, the program established at Georgia Tech will remain at the ready, prepared to deal quickly with future infectious disease epidemics should the need arise, according to Gibson.

“We developed a program that in practice – and psychologically – provided a benefit to community members,” said Weitz, who also serves as the Tom and Marie Patton Chair in Biological Sciences and co-director of the Interdisciplinary Ph.D. in Quantitative Biosciences. “Many people could go get tested and know that they weren’t infectious so that they had a less likely chance of infecting others. Or, if they did end up testing positive, they were able to isolate themselves so they didn’t infect others. That is of significant benefit.”

• TESS MALONE



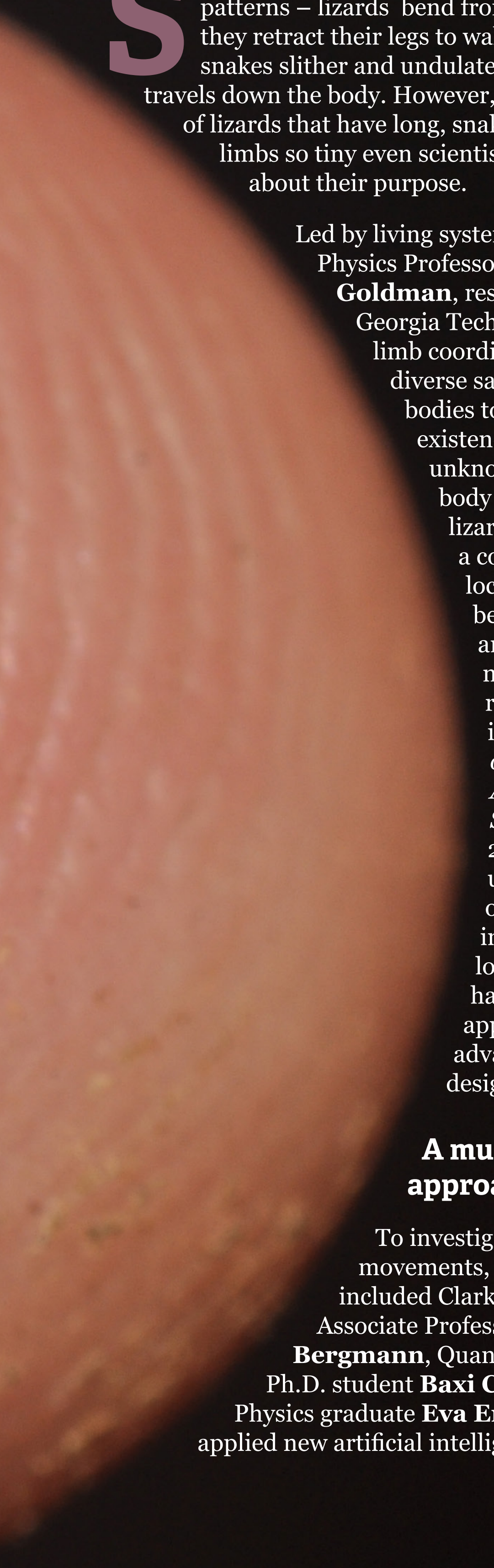
A student completes an asymptomatic Covid-19 test at one of the surveillance testing sites.

THE EDGE of neuroscience, the physics of movement, and robotics

PHOTO: PHILIP BERGMANN

Tiny Limbs and Long Bodies

Coordinating lizard locomotion



Snakes and lizards have distinct body movement patterns – lizards bend from side to side as they retract their legs to walk or run, while snakes slither and undulate, like a wave that travels down the body. However, there are species of lizards that have long, snakelike bodies, and limbs so tiny even scientists have wondered about their purpose.

Led by living systems Dunn Family Physics Professor **Daniel Goldman**, researchers at Georgia Tech studied body-limb coordination in a diverse sample of lizard bodies to uncover the existence of a previously unknown spectrum of body movements in lizards. Revealing a continuum of locomotion dynamics between lizardlike and snakelike movements, their research, published in the *Proceedings of the National Academy of Sciences* in June 2022, deepens the understanding of evolution's implications for locomotion — and has additional applications for advanced robotics designs.

A multidisciplinary approach

To investigate these reptilian movements, the team, which included Clark University Associate Professor **Philip Bergmann**, Quantitative Biosciences Ph.D. student **Baxi Chong**, and recent Physics graduate **Eva Erickson** ('22), applied new artificial intelligence techniques to videos of different lizards' body movements. Known as neural network tracking, the software uses AI to identify features of images — such as legs and bodies — and track those features and their movements.

It has typically been thought that organisms either wiggle like snakes, bend like lizards, or use no body bending at all. When analyzing the footage, however, the researchers saw a wide variety of snakelike waves (traveling waves) and lizardlike movements (standing waves) represented across a diversity of lizard species.

The next question was how to make sense of the diversity of wave patterns. Chong used a mathematical technique developed by particle physicists and control theorists in the last decades. While the theory, now referred to in the locomotion field as geometric mechanics, was initially introduced to study idealized locomotion — to understand how three connected points might swim in water — Chong adapted the theory to include the concept of legs.

Using geometric mechanics, they were able to both see and show the advantage of snakelike waves in short-limbed, elongated lizard locomotion and predict that the advantage arises as the primary thrust generation shifts from the limbs to the body."The advantage of geometric mechanics is that we don't have to explore every possibility of locomotion to determine which one is the best," Chong said.

Findings from the neural network tracking and geometric mechanics enabled the group to form a theory: that the style of lizard movement — whether they move using standing waves to run or a traveling wave to slither — is closely related to degree of limb size and body elongation.

Testing the theory

The researchers tested the theory in two ways. First, they changed the environment, putting sand-dwelling lizards in what they would never come across naturally: sand with air blowing up through it. They observed that short-bodied lizards with strong legs were forced to wiggle their way out, in a movement known as "terrestrial swimming." Essentially, they were able to trick lizards into using snakelike locomotion to move, further supporting the existence of a spectrum of locomotion patterns.

Brachymeles boulengeri — one of the lizards studied by the team — on a leaf. PHILIP BERGMANN

The team then built a robot model to investigate the advantages of lizardlike and snakelike body movements in the intermediate lizard species. Known as a robophysical model, the robot functions as a physicist's model of a living system. With the robot, they can test the predictions of their theoretical model while also gaining insights into the intermediate lizard's biology and locomotion.

> *"We were interested in why and how these intermediate lizards use their bodies and limbs to move around in different terrestrial environments. This is a fundamental question in locomotion biology and can inspire more capable wiggling robots."*
>
> *Daniel Goldman, School of Physics*

"We built the robophysical model to be reconfigurable — we can vary limb length and change how the lizard robot propels itself with the addition and removal of a belly plate," said **Tianyu Wang**, a robotics Ph.D. student and member of Goldman's lab. "We then used the robot to run similar experiments in sand while tracking its motions and performance."

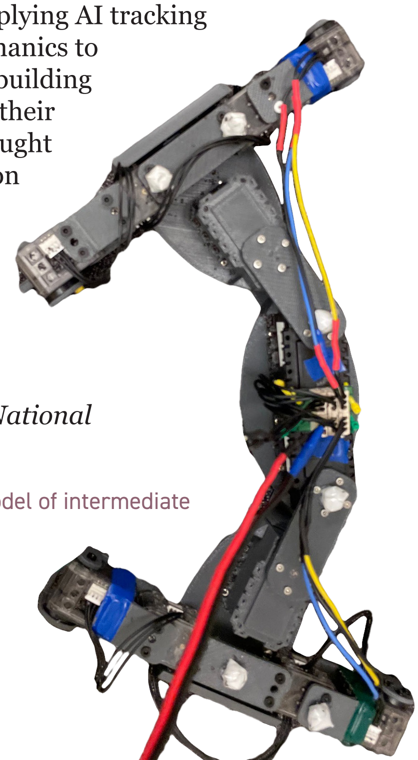
Overall, the team observed that the degree of body elongation and limb reduction in lizards is directly related to how body and limb movements are coordinated, indicating a closely intertwined continuum between body shapes and locomotion style. The researchers even found the tiny limbs to be of significant use to the lizards, not only with propulsion, but also with lifting their bellies off the ground.

"With the robophysical models, we can develop principles that can also inform the next generation of robots that might have to crawl around in rubble or move around in extraterrestrial environments like the surface of moons or planets," Goldman said.

Finally, an important aspect of the study was its multidisciplinary approach. By taking videos from an evolutionary biologist, applying AI tracking software and geometric mechanics to understand movement, and building a robophysical model to test their hypothesis, each student brought individual expertise to bear on the research.

"I have to say, this really was an awesome student-led project," Goldman said.
• CATHERINE BARZLER

Research supported by the National Science Foundation.



The researchers' robophysical model of intermediate lizard species. GEORGIA TECH

Moths and Origami Structures for Innovative Defense Research

Georgia Tech has received two 2022 Multidisciplinary University Research Initiative (MURI) awards. The highly competitive U.S. Department of Defense program supports interdisciplinary teams developing innovative solutions in key areas.

Dunn Family Associate Professor of Physics and Biological Sciences **Simon Sponberg** leads a team discovering how animals like hawk moths strategically use sensing and cognition to make decisions in complex environments. His MURI team focuses on neural systems integration for competent autonomy in decision and control, with the goal of developing an information processing framework that could help the next generation of autonomous bio-inspired and bio-integrated systems.

Sponberg's interdisciplinary team makes complex research possible, and includes School of Mathematics Assistant Professor and recently named Sloan Fellow **Hannah Choi**, who focuses on neural networks.

The second MURI team includes Physics Assistant Professor **Zeb Rocklin**, who is exploring a new class of origami- and kirigami-inspired flexible, lightweight structures capable of transitioning between many stable shapes. These structures could be used in a range of applications, from multifunctional robots with rapidly assembled structures, to force protection elements like origami-inspired shields.

Rocklin shared that "this project benefits from Georgia Tech's ability to develop tight, powerful connections between engineering advanced technologies and developing universal, mathematically rigorous physical theories."

• TESS MALONE

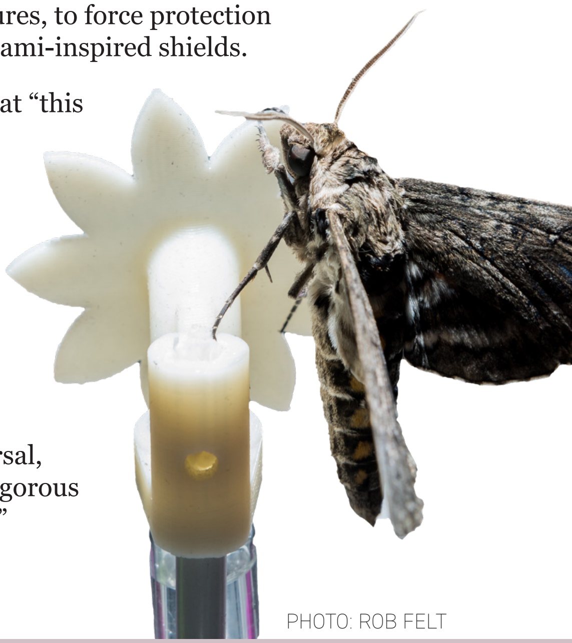
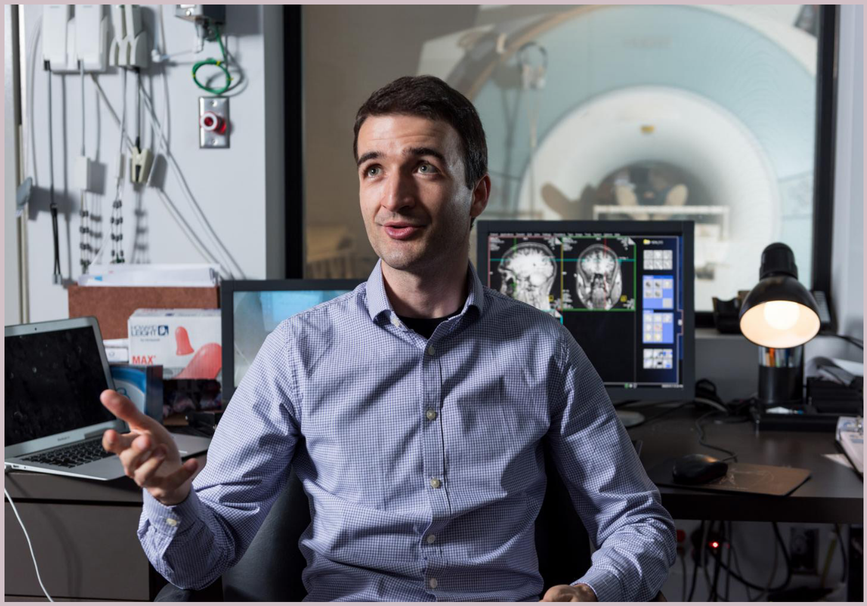


PHOTO: ROB FELT

Dobromir Rahnev Receives Elsevier-Vision Sciences Society Young Investigator Award

School of Psychology Associate Professor **Dobromir (Doby) Rahnev** was awarded the 2022 Elsevier-Vision Sciences Society Young Investigator Award for fundamental contributions to our understanding of perceptual decision making and visual metacognition. The award, sponsored by Vision Research, is given to an early-career vision scientist who has made outstanding contributions to the field.



Rahnev's research seeks to uncover the computational and neural bases of perceptual decision making. His early pioneering work on attention-related subjective biases has inspired new lines of investigation and stimulated debates among philosophers. His more recent work has uncovered the sources of suboptimality in perceptual decision making and developed improved models of visual metacognition. Rahnev's research exemplifies open and high-quality science that produces fundamental discoveries about how humans make perceptual decisions. •

ART: NIH

Stopping Chemo Neuro Damage Before it Starts

Multidisciplinary team led by Tim Cope receives new grant from NIH supporting work focused on long-term effects from platinum-based cancer drugs

About half of the cancer patients who receive chemotherapy are treated with drugs made from platinum-based compounds, or PBCs. While these drugs have demonstrated real success in improving cancer survival rates, there are off-target side effects. Neurotoxicity, one of the more prevalent and significant side effects, often causes pain, fatigue, weakness, strange sensations, and difficulty with balance — common symptoms known collectively as chemotherapy-induced neuropathy.

For many clinicians, this has been a fair trade-off — powerful, toxic cancer drugs save lives, but kill neurons. It's the price of survival.

Georgia Tech postdoctoral researcher **Stephen Housley** isn't buying it.

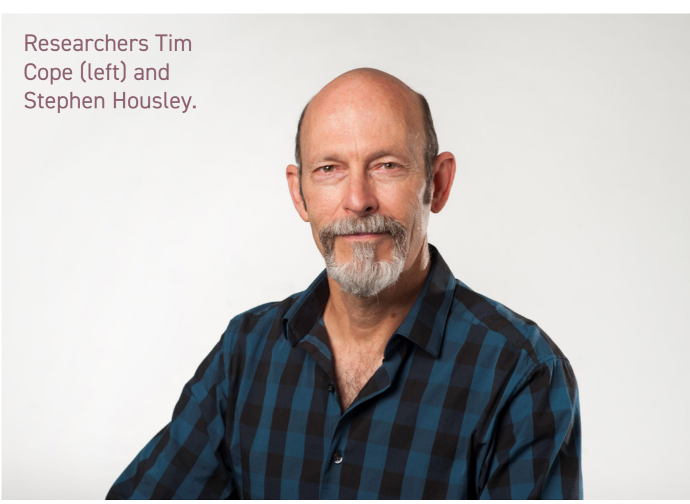
"The basic position has been, 'we cured your cancer, but you have neurotoxin damage, so let's manage those symptoms.' Because when neurons become dysfunctional, it is challenging to correct it," said Housley, a neuroscientist, physiologist, and licensed physical therapist who works with **Tim Cope**, professor in the School of Biological Sciences and the Wallace H. Coulter Department of Biomedical Engineering at Georgia Tech and Emory University, and with cancer researcher **John McDonald**, professor in the School of Biological Sciences.

But what if the nerve cells didn't have to become dysfunctional? What if you could stop the damage before it even begins? Housley and his colleagues aim to find out with help from a new NIH National Cancer Institute R01 grant, "which will help us really drill down into some of the mechanisms of neurotoxicity experienced by cancer survivors globally," said Housley, who is leading the research effort.

Cope, principal investigator on the $2.5 million grant, added, "building on our recent discoveries, we're taking a new direction that has the promising potential to identify novel targets for treating neurotoxic damage to the neurons that are responsible for movement disorders."

Damage from the start

Cope and Housley work in the pre-clinical phase of cancer treatment, developing and studying animal models to mimic the human condition, so they can study the effects of chemotherapy on the individual neurons and circuits that human behaviors and perceptions emerge from. Previous studies from other labs have determined that these drugs are causing the nerve damage by themselves, but the Georgia Tech team discovered a more nuanced set of circumstances.



Researchers Tim Cope (left) and Stephen Housley.

> *"If you are diagnosed with cancer and are treated with these drugs, in the great scenario, you go into remission and stop the drugs. The problem is, the side effects don't stop."*
>
> *Stephen Housley, School of Biological Sciences*

"Biology is more complex than that," Housley asserted, explaining that the majority of previous studies have focused only on the effects due to chemotherapy. "The cancer interacts with the chemotherapy, changing the underlying causes and worsening the nerve dysfunction long-term."

"If you are diagnosed with cancer and are treated with these drugs, in the great scenario, you go into remission and stop the drugs," he added. "The problem is, the side effects don't stop. They actually evolve and convert into something a bit different than what was happening early on. And they persist for a long time, in many cases over a decade."

Housley and Cope's work on the chronic phase of cancer highlights that there is a likely a link between what happens in the earliest stages of treatment and the long-term probability of developing neurologic disorders.

"While a patient is in the chair getting chemotherapy, they will not only have sensory problems, but an increased stimulation, often perceived as being painful or hypersensitivity to cold," Housley said. "The speed at which these drugs can impact the nervous system is stark. The motor system that helps us move is being affected in the course of minutes or hours."

In response to the infusion of these PBC drugs, the system overcompensates. The hyper excitability goes in an opposite direction. So now, instead of an electrical jolt, the system slows down: when reaching for and grabbing a cup of coffee, the collaboration between your motor and sensory systems gets fuzzy. Is your sensory system correctly anticipating the weight of the cup while your motor system grabs and lifts? Will the cup slip and spill hot coffee on your lap?

The multidisciplinary team wants to stop the initial hyper excitability from happening in the first place. Through a process called in vivo electrophysiology, they use glass electrodes to study the behavior of single cells as they respond to stimulation, such as that caused by the reaction of cancer to a PBC. With these approaches they are testing new pharmacologic and gene therapy approaches to prevent hyper excitability.

"It's a challenging but powerful approach," said Housley. The ultimate goal is to block the neurotoxic effects of the drugs, so that they can beat the cancer and not harm the patient's long term health and quality of life. "Through these experiments, we want to knock out the various drivers of what we suspect is causing this serious problem, and ultimately prevent the long-term consequences of these neurological disorders."

• JERRY GRILLO

PHOTO: SHEPHERD CENTER

Major Gift to Strengthen Tech-Emory Neurorehabilitation Research

Thanks to a $1 million gift from **Dana** and **Jack McCallum** (BIO '66), the Applied Physiology Ph.D. program at Georgia Tech will continue to advance rehabilitation science with the creation of the Jack and Dana McCallum Neurorehabilitation Training Program.

A collaborative initiative between the Applied Physiology program, the Emory University School of Medicine, and Shepherd Center's Crawford Research Institute, the program will train graduate students in neurorehabilitation research and clinical practices. The investment will also drive new major research focused on understanding the neurophysiological basis for injury and recovery and on the preclinical development of potential therapies.

Edelle Field-Fote, a professor with joint appointments in the Emory University School of Medicine and Applied Physiology at Georgia Tech, who also serves as director of spinal cord injury research at the Shepherd Center, shared that she is "most excited by the great potential that this program has for advancing the clinical care and foundational sciences related to neurorehabilitation."

• AUDRA DAVIDSON

To the Third Degree: Nine Questions with the Kashlan Triplets

Three years, three neuroscience degrees, and three future medical professionals

From left: Zane, Adam, and Rommi Kashlan. JASON GETZ, ATLANTA JOURNAL CONSTITUTION

As triplets, **Adam**, **Rommi**, and **Zane Kashlan** are used to doing things together. After three years at Georgia Tech, the triplets added one more thing to the list: graduating with highest honors from the Undergraduate Program in Neuroscience.

We spoke with the Kashlan triplets about their time at Georgia Tech, the lessons they've learned, and what's next on the horizon.

1. Why Neuroscience at Georgia Tech?

Zane: The Neuroscience program at Georgia Tech is unique in that it's incredibly interdisciplinary. As Neuroscience majors, students can freely take courses in Georgia Tech's top-ranked programs like engineering, computer science, and even business on top of a regular course load filled with biology and other science core curricula.

In addition, the broad nature of the curriculum offers students an opportunity to explore all areas of Neuroscience, including Biological Neuroscience, Neuroengineering, Computational Neuroscience, and several other pathways that help develop essential lifelong skills. It is a fantastic STEM major to pick as students who want to explore different career paths and pick up different skills. We enjoyed charting our individual experiences within Neuroscience and are so grateful for the advisors and professors who supported us along the way.

> *"[Neuroscience] is a fantastic STEM major to pick as students who want to explore different career paths and pick up different skills."*
>
> *Zane Kashlan, NEURO '22*

2. What made you all decide to go to Georgia Tech together?

Zane: Georgia Tech has always felt like a second home to us. We were born and grew up in the Atlanta area.

Georgia Tech offered a strong list of notable faculty members. The modern campus is big enough to explore different interests in a wide variety of subjects. Tech offered a special place for us to be challenged, make new friends, and grow independently as a trio.

3. Coolest thing(s) you've learned about the human brain?

Rommi: The most remarkable thing I've learned about the human brain is how much we don't know about it. Out of every meticulous detail we know about human physiology and function we have barely scratched the surface of our cognition and thinking. This leaves so much room for exploration in neuroscience research because there is so much yet to be uncovered.

> *"The most remarkable thing I've learned about the human brain is how much we don't know about it."*
>
> Rommi Kashlan, NEURO '22

4. What's your advice for young people interested in STEM research?

Zane: I think the most important part of being interested in STEM is just that — curiosity. Being curious about everyday scientific phenomena is the crux of being a good researcher or engineer. Just by staying curious so many doors are open for learning. A student can start with some YouTube videos, hone that passion by taking a course or joining a lab, and who knows, maybe one day that passion will turn into a career.

5. Advice for students who are interested in a career in health and medicine?

Zane: Building a career in medicine takes a long time, maybe up to 12 years or more after college. Get involved through internships and research as early as your first year, and take the time to figure out what about medicine and health interests you. There are so many opportunities not only within the scope of being a clinician but also in medical research, medical technology, medical business, and medical law – going down the path of a physician is certainly not the only way to have a career in health.

I especially recommend taking a gap year or two before making such an impactful commitment to exploring all potential career opportunities that might interest you before dedicating yourself to a life in medicine.

6. What's the most important thing you've learned through Tech?

Rommi: Problem-solving, how to persevere, self-motivation, and putting things into perspective.

7. What are your plans for the rest of 2022 and beyond?

Adam: After graduating in the spring, I moved to Boston to work as a research assistant in the Woolf Lab at Harvard Medical School. We study non-opioid-based analgesic drugs used in the treatment of chronic pain. I'll apply to medical schools next summer, and want to pursue a career as a physician focusing on improving immigrant and refugee health in the United States – my passion since middle school.

RIGHT PHOTO: JASON GETZ, ATLANTA JOURNAL CONSTITUTION

Zane: In late April, I switched my research work from Yale Medical to the Woolf Lab at Harvard Medical. In the future, I plan to combine my passion for research and medicine as a physician-scientist to improve patients' lives suffering from neurodegenerative disorders like Alzheimer's.

Rommi: I have been volunteering at various clinics. Now that I have taken the MCAT, I am starting my research work at Harvard Medical and Mass General. We study cognitive impairment and effects in microglia in the brain with Covid and HIV patients.

> *"...knowing that your years of hard work through trials and tribulations have finally amounted to something great is amazing."*
>
> Adam Kashlan, NEURO '22

8. What was your most memorable experience from the past few years?

Adam: I would probably have to say graduation. While it is a bit cliché, knowing that your years of hard work through trials and tribulations have finally amounted to something great is amazing.

9. Best part of being a Yellow Jacket?

Zane: The decision has to be between making great friends and calling such an amazing school home.

Rommi: Knowing that I am ready to face any new challenge, confident that I will do well.

Adam: Developing many relationships and connections with friends, mentors, and professors at the school has continued to benefit me even after graduation. Also, coming from Georgia Tech opens up many doors and opportunities that you otherwise wouldn't get at other schools. • JESS HUNT-RALSTON

Thackery Brown Probes the 'Black Box Problems' in Cognitive Neuroscience

Thackery Brown, an assistant professor in the School of Pyschology, has long sought to solve the "black box problems" of the human mind.

Cognition, the mental process of acquiring, using, and storing knowledge, will continue to dominate Brown's research, thanks to a two-year funding grant from the Shurl and Kay Curci Foundation.

"[Studying cognitive neuroscience enables us] to get behind the curtain and understand why cognition succeeds and fails, and potentially study ways of improving it."

Thackery Brown, School of Psychology

It's part of a busy season for Brown. In addition to the Curci funding, he's recently received a research grant from the National Institute on Aging, and he and members of his lab published a new study on memory recall and spatial navigation.

Thackery Brown at Georgia Tech's Center for Advanced Brain Imaging. THACKERY BROWN

The Curci grant "is a great honor," Brown said, and the research the grant will fund "could potentially change the way we approach memory research." Brown wants to combine traditional brain imaging tools like magnetic resonance imaging (MRI) and electroencephalography (EEG) with machine learning in a unique way.

"One of the challenges, especially among young scientists, is having opportunities to do research that's really on the cutting edge of our field," Brown shared. "That's where it's more high-risk, high-reward. It's harder to support big ideas, especially when you're junior faculty, so this is a great opportunity to get at the forefront of the field's biggest questions."

• RENAY SAN MIGUEL

Hannah Choi Named Sloan Fellow for Mathematical Neuro Research

School of Mathematics Assistant Professor **Hannah Choi** was among 118 early career researchers across North America to receive prestigious Sloan Research Fellowships. Choi plans to use the grant to expand on current biological neural network research projects.

"I am extremely excited and honored to be named a Sloan Fellow," Choi shared. "I am deeply grateful to my research group members, mentors, colleagues and collaborators who made this possible, and I appreciate support from the School of Mathematics and the College of Sciences very much."

• RENAY SAN MIGUEL

PHOTO: HANNAH CHOI

Hammering Out a Connection Between Visual Gaze and Motor Skills Learning

For his recent research on motor skills, visual learning, and their effects on human physiology, School of Biological Sciences Associate Professor **Lewis Wheaton** and his team went all the way back to the Paleolithic Era to study a very retro skill: stone toolmaking.

“One of the cool things about this particular study,” Wheaton said, “is this opportunity to look at a completely novel motor task, something most people have no idea how to do — and that’s making a stone tool.”

The new research, published in *Communications Biology*, attempts to fill in the gaps when it comes to the science of how we learn complex motor skills — and what may be required to relearn them.

Wheaton conducted the research with former Applied Physiology students **Kristel Yu Tiamco Bayani** (Ph.D. ‘21) and **Nikhilesh Natraj** (Ph.D. ‘15), plus three researchers from Emory University’s Department of Anthropology.

“The overall motivation was to determine if we could see any kind of emerging relationship between the perceptual system and the motor system, as somebody is really trying to learn to do this skill,” Wheaton said. Those are important processes to understand, he added, not just for how people attain complex motor skills learning, but what would be needed for motor relearning, as in a rehabilitation setting.

The test subjects in the study watched videos of paleolithic stone toolmaking for more than 90 hours of training. The subjects’ visual gaze patterns and motor performance were checked at three different training time points: the first time they watched the video, at 50 hours of training, and at approximately 90 hours. Everybody was able to make a stone tool (with varying degrees of success) at 90 hours, but some picked up the skills at 50 hours.

Researchers Lewis Wheaton (left) and Kristel Yu Tiamco Bayani.

“Part of the study was to understand the variability where they are visually focused as they get better at the task,” he said.

That’s how Wheaton’s team found there are certain parts of the skills learning that connect better to gaze, but others that connect better to the physical act of making a stone tool. “As you’re going through time, your motor abilities are changing, and at some point that allows you to watch somebody else perform the same task differently, suggesting you’re able to follow the action better, and pull more information from the video in a much clearer way.”

The study not only found a connection between gaze and motor skills learning, but that the connection evolved as the learning went on. The next step in this research, Wheaton said, should include brain imaging “heat maps” to determine where learning takes place with this process.

That could also help Wheaton’s team apply these lessons for rehabilitation purposes.

“That’s the link between that and some of the other work we’ve done in a rehab context,” he said. “If you’re watching somebody perform a task, if you’re undergoing rehab, there are different ways you’re watching the task. You’re not always watching it the same way. Maybe it depends on how good you are, or how you’re impaired, but all those variables play a role into what you’re visually pulling out” of the rehab training. • RENAY SAN MIGUEL

“One of the cool things about this particular study is this opportunity to look at a completely novel motor task, something most people have no idea how to do — and that’s making a stone tool.”

Lewis Wheaton, School of Biological Sciences

Christina Ragan: Celebrating Brain Awareness Week — and Neuroscience for All

From the science of crafting to a science improv show, Georgia Tech has partnered with the Atlanta Science Festival in filling the month of March with science outreach events since the annual festival was founded in 2014. And after receiving a seed grant from the Dana Foundation for the second year in a row, **Christina Ragan** was able to partner with the festival to host her outreach "Super Bowl" — Brain Awareness Day.

With a passion for inspiring others and making neuroscience more accessible, Ragan, a faculty member and lecturer in the School of Biological Sciences and the director of Outreach for the Undergraduate Program in Neuroscience at Tech, is a leader in developing neuroscience-related outreach events.

For the past two years, Ragan has been annually awarded a $1,500 seed grant from the Dana Foundation to design that kind of outreach in celebration of Brain Awareness Week, the Foundation's global campaign dedicated to fostering curiosity and enthusiasm for brain science.

As the 2020 Carol Ann Paul Neuroscience Educator of the Year, Ragan's dedication in the space has already made an impact on campus. We spoke with Ragan to learn more about Brain Awareness Day and her approach to reaching community members beyond campus.

"I love that we get to involve our undergraduates in our outreach events, so they get to teach others all about the brain. I think it's important for the public to learn about the nervous system since it plays such a critical role in pretty much everything we do. Even when we are asleep or daydreaming, our brain is hard at work."

Christina Ragan, School of Biological Sciences

What is Brain Awareness Week, and why do you think it's important?

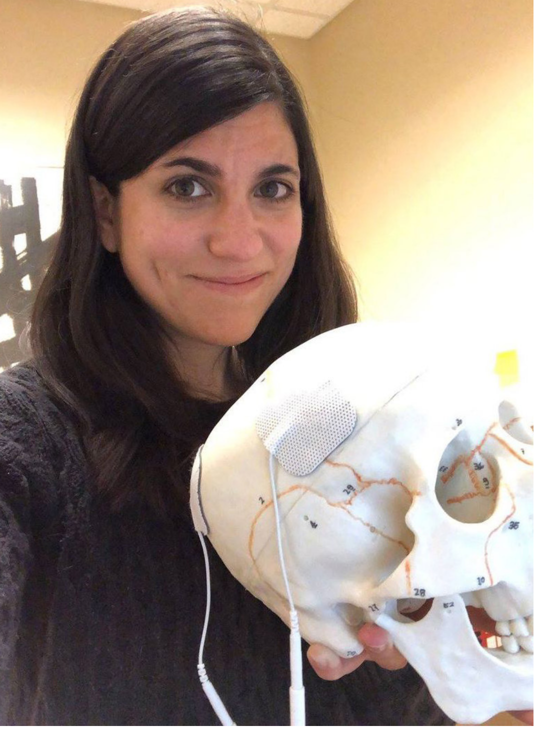
Brain Awareness Week, organized by the Dana Foundation, is a great way to share neuroscience with the public in a way that is engaging, fun, and accessible to a broad audience. We [celebrated] Brain Awareness Week in three ways: 1. Our Brain Awareness Day event as part of the Atlanta Science Festival, 2. Laboratory Tours for High Schoolers during the Brain Awareness Day event, and 3. Visiting the Drew School. My organizing committee of Neuro undergraduates (**Rommi Kashlan**, **Brenna Cheney**, **Claire Deng**, and **Payton McClarity-Jones**) was extremely helpful in planning these activities.

I love that we get to involve our undergraduates in our outreach events, so they get to teach others all about the brain. I think it's important for the public to learn about the nervous system since it plays such a critical role in pretty much everything we do. Even when we are asleep or daydreaming, our brain is hard at work.

Science doesn't need to be restricted to folks who have formal degrees. Every time a kid asks, "but why?" they are acting just like a scientist!

Seed grants are often given to help researchers or faculty begin to develop new projects or programs. What project or program do you hope to develop with this grant?

I would love to get involved with folks working in STEM education in the greater Atlanta area to assess the outcomes of events like these. Who are we reaching and who do we still need to increase our efforts to? How can we reach the most people? What kinds of events not only promote students to pursue STEM careers, but also encourage appreciation and literacy



Christina Ragan holding a student-designed electroconvulsive-therapy model for a Brain Awareness Day event.

for science for those who aren't in STEM fields? I'd also like to form strong relationships with area schools so we can share our neuroscience demonstrations with them as well.

This is the second year I have received this grant and I am so excited that we can use it to increase the number of resources we can use for neuroscience outreach. It is a tremendous honor to be recognized for something I consider so rewarding.

I would love it if attendees for our Atlanta Science Festival event walked away excited, inspired, and curious about neuroscience. I hope that this year's attendees become regular attendees annually and spread the word to their friends. I would love for attendees to tell their parents and teachers about it so we can arrange more school visits, especially to schools who may not always get opportunities.

Christina Ragan challenging attendees with optical illusions at a previous Brain Awareness Day Neuroscience event held at Michigan State University, where Ragan was a postdoctoral fellow. PHOTOS: CHRISTINA RAGAN

> *"Science doesn't need to be restricted to folks who have formal degrees. Every time a kid asks, 'but why?' they are acting just like a scientist!"*
>
> Christina Ragan, School of Biological Sciences

What's your favorite neuroscience outreach event or program that you've done?

I call Brain Awareness Day (the event that took place as part of the Atlanta Science Festival) my "Super Bowl." I love seeing all the attendees engaged with the presenters and the look on their faces when they learn the neuroscience behind the activity. It's really funny when their minds are just blown away after the gears start turning and they figure something out.

Why do you think this kind of outreach is important?

Neuroscience outreach is important, especially for middle school girls, because that is the time in their lives when they are unfortunately taught that being smart or liking science isn't for girls. I don't expect everyone who attends our outreach events to become scientists, but I do aim to encourage an appreciation for science and to think like scientists.

We are truly in the Information Age, and it is our job as educators to help students learn how to evaluate all this information that is literally at their fingertips.

How do you envision outreach playing into the future of Georgia Tech's Neuroscience program as it continues to develop?

I think outreach can have a positive impact for our Tech students and for the community. I envision outreach being something that our program is known for to provide our students an opportunity to engage with the public in a way that is fun and an application of what they have learned in their classes.

I think that what we offer students in the classroom is just a small portion of their education. I would love to foster relationships with other schools and youth organizations to make neuroscience accessible to all. • AUDRA DAVIDSON

THE EDGE

of quantum systems, materials, computing, and information science

Bringing Order to 'Excitable' Particles to Unlock Better Batteries, Sensors, and Lasers

Organic semiconductors already provide the energy behind optical technologies inside television displays, solar cells, and lighting fixtures. Their molecular carbon-based structure makes them cheaper to produce, more flexible, of lighter weight, and more environmentally friendly than silicon-based or composite semiconductors. The future in more applications is bright — if scientists can learn more about harnessing their ability to react to and produce light.

A team of Georgia Tech researchers is one step closer to understanding those properties. For the first time, tracking and measurement are being applied to organic semiconductor photoexcitations: particles put into "excited" or energized quantum states by light.

The semiconductors' primary photoexcitations, called Frenkel excitons, dictate the optical qualities in those semiconductors. They can, in principle, form bonded pairs called biexcitons, but these have never been identified unambiguously. Quantifying those reactions will help researchers learn more about their properties to unlock future uses, such as more efficient and sustainable batteries and solar cells, biosensors, and new types of lasers.

"It's a window into the basic electronic structure and properties of these materials," said study co-author **Carlos Silva Acuña**, a professor with joint appointments in the School of Chemistry and Biochemistry and School of Physics, "but also into these tech applications we care about. How do we convert electrical energy to light? Or in photovoltaic applications, how do we convert solar light into electrical power? It's more about understanding and discovering the very basic fundamental properties of materials that will allow the design of tailored materials that optimize a particular function."

Silva Acuña and **Natalie Stingelin**, professor in the School of Chemical and Biomolecular Engineering and chair of the School of Materials Science and Engineering, led a team of researchers that tweaked traditional spectroscopy — how light or any other form of radiation is emitted and absorbed by materials — to track and measure the energy coming from Frenkel biexcitons. The researchers wanted to know how those photoexcitations form "bonds" between each other, how excitons find the right partners to form biexcitons, and how stable those exciton partners are.

The scientists used different spectroscopy techniques such as non-linear and coherent versions, which give researchers more flexibility in determining the energies flying back and forth between pairs of excitons. "The idea is an advanced spectroscopy that allows us to dissect interactions between excitations," Silva Acuña said. "It's designed to measure or resolve the interaction energy between different photoexcitations," adding that the researchers can dissect with more detail where light from the biexcitons falls on the spectrum.

Those interactions are the foundation for any future quantum (atomic and subatomic) science applications for organic semiconductors, "because all the quantum phases we might want to induce are all governed by their interactions, and the interactions between photoexcitations are key."

The global organic semiconductor market is expected to grow by $90.8 billion between 2020 and 2024, according to Berkshire Hathaway company Business Wire. Yet while composite semiconductors have well-studied and defined optical signatures, that's not quite the case for organic semiconductors. "We could not

Left: Organic thin-film transistors for organic semiconductors under continuous testing on a probe station. ROB FELT

"How do we convert electrical energy to light? Or in photovoltaic applications, how do we convert solar light into electrical power? It's more about understanding and discovering the very basic fundamental properties of materials that will allow the design of tailored materials that optimize a particular function."

Carlos Silva Acuña, School of Physics, School of Chemistry and Biochemistry find a clear optical signature of biexcitons," Silva Acuña said. "That's what has made them more challenging. There is a lot of theoretical prediction and calculation, but not really any experimental measurement" preceding the new Georgia Tech research, he explained.

"We can for the first time unambiguously identify bound excitons and characterize their nature. They're attracted to what energy, repulsed by what energy, and why? How do those details relate to molecular structure?" he said. "What would we need to change to change those properties? How do we discover new materials with tailored properties?"

Silva Acuña also noted an unexpected finding in the research: Excitons that interact with each other in different polymer chains attract each other to form biexcitons — while excitons in the same polymer chain repel each other. "It's a little bit counterintuitive that you can have two excitons repel each other, and yet they bind," he said.

If the interaction energy between excitons is strong, a lot of excitons will end up as bound biexcitons, Silva Acuña added. If science decides that can help add more functions to those materials, "Maybe we can design them to be even more strongly bound." Or if it's decided that those bonds need to be weaker for certain functions, "How can we turn them off? It's all about material discovery."
• RENAY SAN MIGUEL

An organic photovoltaic device. ROB FELT

Henry "Pete" LaPierre Earns Prestigious Sloan Fellowship

Henry S. "Pete" La Pierre, assistant professor in the School of Chemistry and Biochemistry, is among 118 early career researchers across the United States and Canada named as 2022 Sloan Fellows.

"Today's Sloan Research Fellows represent the scientific leaders of tomorrow," said **Adam F. Falk**, president of the Alfred P. Sloan Foundation. "As formidable young scholars, they are already shaping the research agenda within their respective fields — and their trailblazing won't end here."

Sloan Research Fellowships are some of the most competitive and prestigious awards available to early career researchers. They are also often seen as a marker of the quality of an institution's science faculty — and proof of an institution's success in attracting the most promising junior researchers to its ranks. Since the first Fellowships were awarded in 1955, nearly 50 faculty from Georgia Institute of Technology have received the honor.

La Pierre leads the La Pierre Research Group, with an aim to "disentangle the complex electronic structure of f-block materials." F-block elements, also known as lanthanides and actinides, are heavy metals found at the bottom two rows of the Periodic Table.

La Pierre will use the award funds to support postdoctoral fellows and graduate students to take on several new lines of inquiry in lanthanide and actinide magnetism.

"I am quite excited to be included among this year's Sloan Research Fellows," La Pierre shared. "It's (a group of) extremely talented colleagues. I am also particularly humbled by my colleagues' support for this award." • RENAY SAN MIGUEL

Folding Science Into Art for Origami

For **Zeb Rocklin**, an assistant professor in the School of Physics, it was the intersection of art and science — or rather, using the math in origami principles to enhance science — that led to Sigma Xi awarding his work as a best research paper.

"Hidden symmetries generate rigid folding mechanisms in periodic origami," published in the *Proceedings of the National Academy of Sciences* (PNAS), detailed efforts to find mathematics-based structure and symmetry deep inside the folds of origami, the ancient Japanese art.

The paper, which Rocklin co-authored with former graduate student **James McInerney**, "gives us access to a lot of mathematical technology," Rocklin said, by looking at origami sheets in a new way, which could lead to even more practical scientific and engineering applications for origami.

"I'm a soft matter physics guy, so I study how the geometric structure of a system controls how it changes shape when you push on it," Rocklin said. "On the one hand it's something you can hold in your hand and feel it and see it moving in real space, but on the other hand, it embodies and obeys these really austere algebraic structures."

Since 1947, the Georgia Tech Chapter of Sigma Xi has annually honored faculty and students for their research at the annual Spring Awards Banquet. The Georgia Tech Sigma Xi Research Awards are made possible by the support of the Georgia Tech Research Corporation and the Ferst Foundation.

Sigma Xi, The Scientific Research Society, founded in 1886 at Cornell University, is the honor society of scientists and engineers that recognizes scientific achievement. Its mission is to enhance the health of the research enterprise, foster integrity in science and engineering, and promote the public's understanding of science for the purpose of improving the human condition. • RENAY SAN MIGUEL

A trio of research achievements highlight School of Physics Associate Professor **Martin Mourigal**'s *trajectory to becoming a nationally recognized expert in quantum science and materials science research.*

Through these features, learn a little more about Mourigal's research, a recent recognition, a new role with Georgia Tech's Institute for Materials, and how Mourigal's neutron experiments have helped unlock a decades-old mystery.

The College of Sciences' Neutron Scattering Sage, Martin Mourigal

Scientists bombard materials with neutrons. By measuring how those sub-atomic particles are scattered off, it is possible to re-construct the magnetic behavior of matter at the nanoscale and predict material's properties — hence the term "neutron scattering."

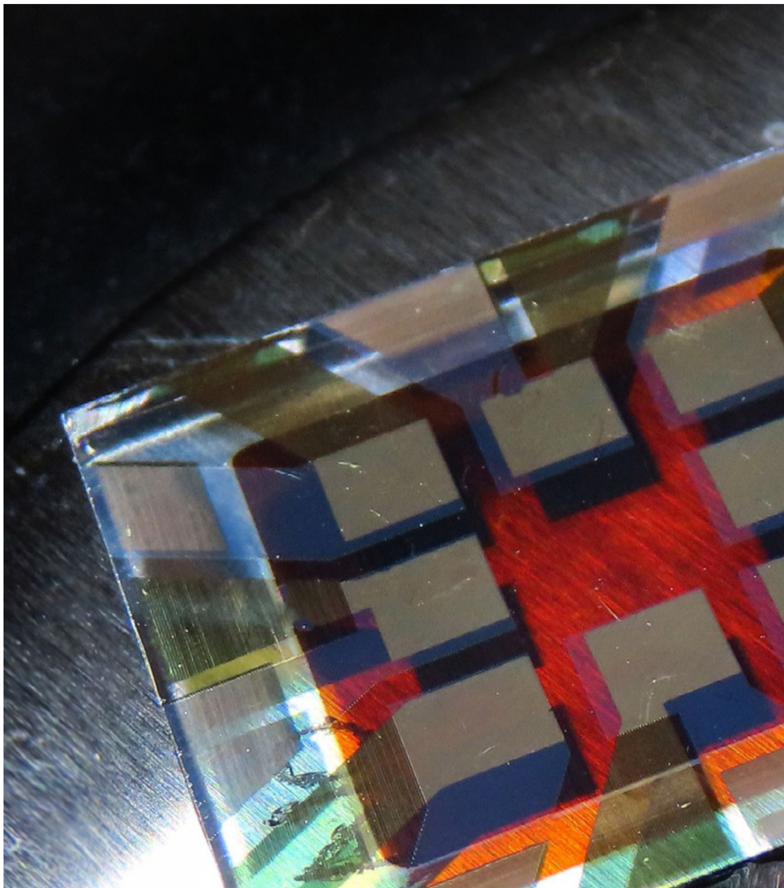
Martin Mourigal, an associate professor in the School of Physics, recently won the 2022 Science Prize of the Neutron Scattering Society of America (NSSA) "for significant and insightful use of neutron inelastic scattering in the study of quantum materials."

The NSSA established the Science Prize to recognize a major scientific accomplishment or important scientific contribution within the last five years using neutron scattering techniques.

Mourigal is widely known for his research on novel magnetic quantum materials.

He uses neutron scattering to characterize the magnetic fluctuations, and the short- and long-range magnetic order in these materials, to gain insight into their underlying quantum behavior.

Learning about that behavior can lead to major advances in energy materials, computing and semiconductors, and secure communications, to name just a few. • RENAY SAN MIGUEL AND THE NSSA



Georgia Tech's Institute for Materials (IMat) Builds New Foundation for Future Research, Names Mourigal to Science Advisor Position

Materials research spans a broad spectrum from fundamental science to engineered products and their societal impacts. Innovation and breakthroughs often come from exchanging ideas, tools, and concepts between scientists, mathematicians, engineers, computer scientists, social scientists, and industry researchers and leaders. Recognizing the critical role of fundamental science and the need for the Institute for Materials (IMat) to be rooted in an inclusive and active community of interdisciplinary researchers, IMat has created a new Science Advisor position and a team of initiative leaders to shape the future of IMat.

Science Advisor: Martin Mourigal

Martin Mourigal's laboratory focuses on the magnetic properties of quantum materials. His research primarily relies on neutron spectroscopy to probe the exotic states of matter such as spin liquids, frustrated magnets, and spin-multipolar phases. In addition to his own lab research, Mourigal is co-director of the Georgia Tech Quantum Alliance, a university-wide program on quantum sciences and engineering.

Meet the 2022-23 IMat initiative leads:

- Characterization: Remote and Real-time Measurements | **Faisal Alamgir**
- Circularity in Civil Infrastructure Materials and Systems | **Russell Gentry**
- Materials and Interfaces for Catalysis and Separations | **Marta Hatzell**
- Quantum Responses of Topological and Magnetic Matter | **Zhigang Jiang**
- Circularity of Biopolymers | **Kyriaki Kalaitzidou**
- C.H.I.P.S. Initiative - Electronic and Ferroic Materials | **Asif Khan**
- Materials for Energy Storage | **Matthew McDowell**
- Materials in Extreme Environments | **Richard W. Neu**
- Materials for Quantum Science and Technology | **Chandra Raman**
- Polymer Electronics and Photonics | **Natalie Stingelin**
- Materials for Biomedical Systems | **W. Hong Yeo** • CHRISTA M. ERNST

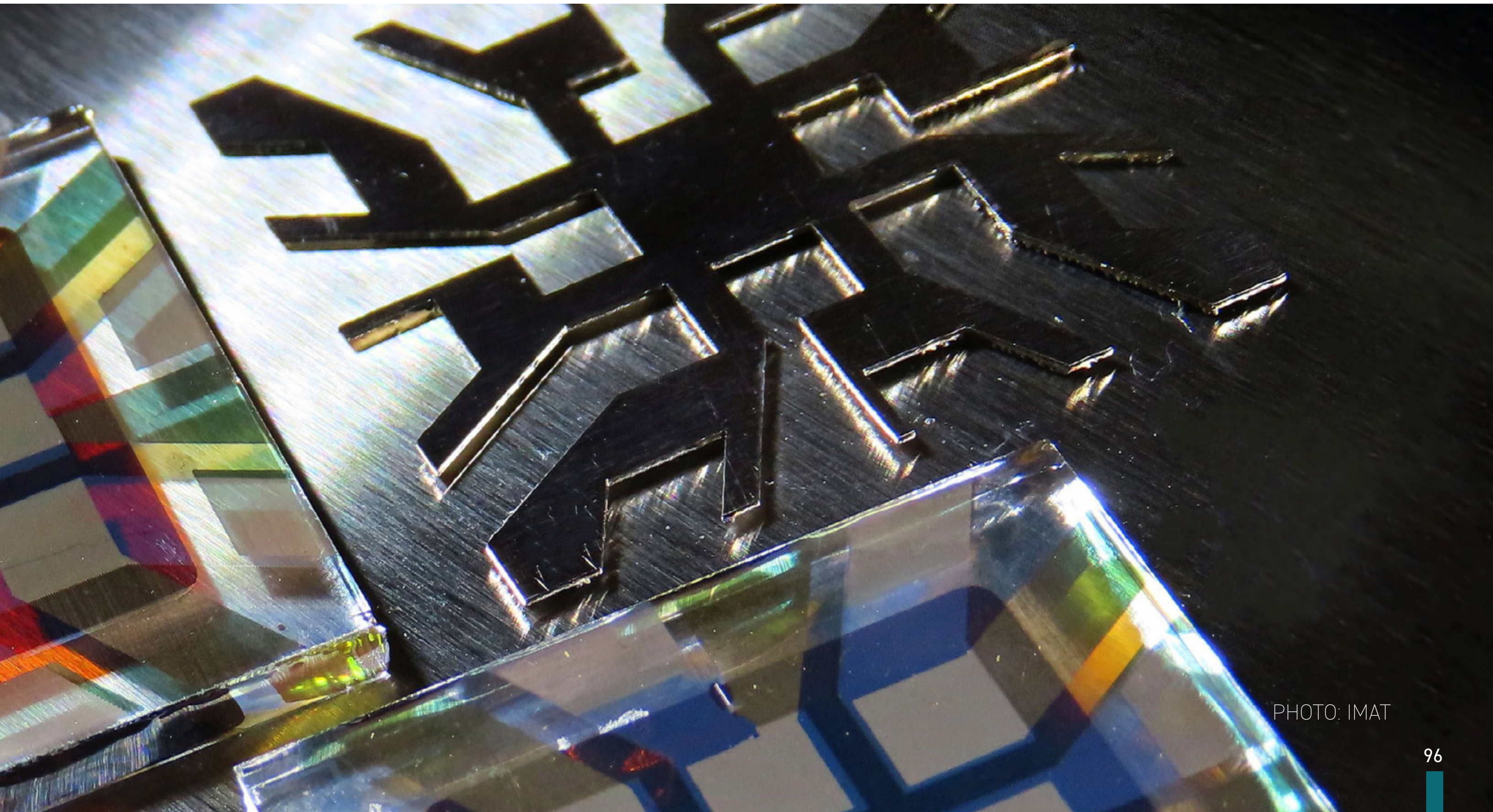
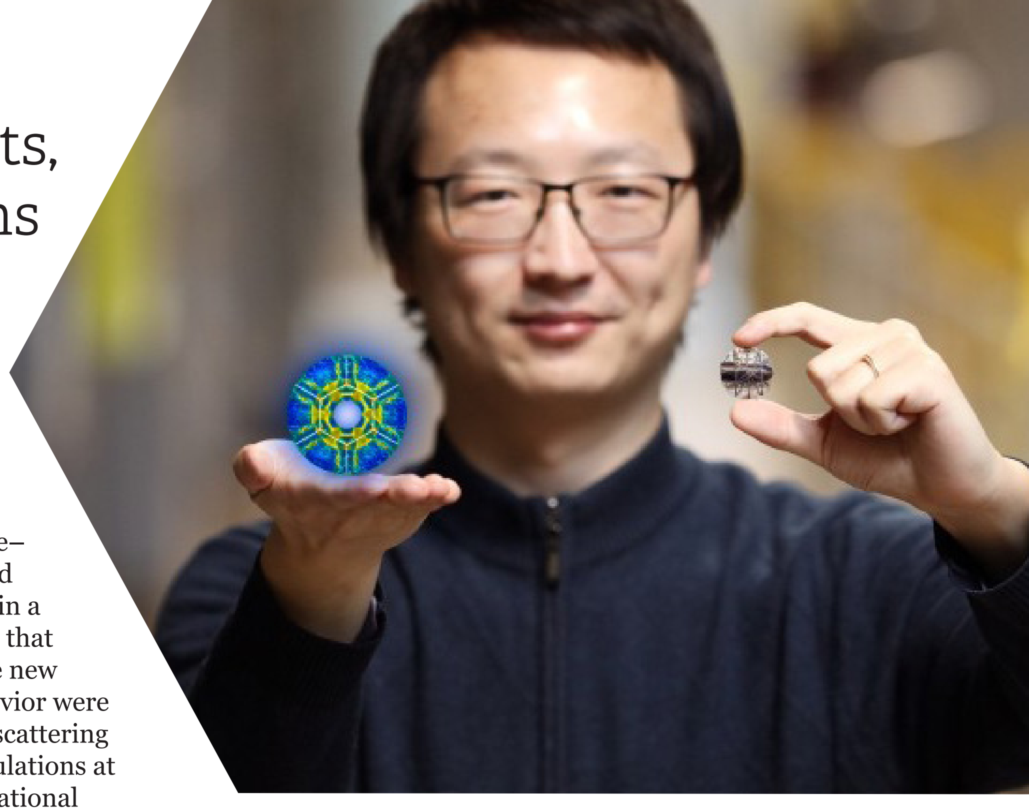


PHOTO: IMAT

Frustrated Magnets, Scattered Neutrons

How Tech's quantum science research helped uncover new properties in an old material



Researcher Xiaojian Bai and his colleagues used neutrons at ORNL's Spallation Neutron Source to discover hidden quantum fluctuations in a rather simple iron-iodide material discovered in 1929. ORNL, GENEVIEVE MARTIN

Researchers from Georgia Tech and the University of Tennessee–Knoxville uncovered hidden and unexpected quantum behavior in a rather simple iron-iodide material (FeI2) that was discovered almost a century ago. The new research insights into the material's behavior were enabled using a combination of neutron scattering experiments and theoretical physics calculations at the Department of Energy's Oak Ridge National Laboratory (ORNL).

The team's findings — published in the journal *Nature Physics* — solve a 40-year-old puzzle about the material's mysterious behavior, and could be used as a map to unlock a treasure trove of quantum phenomena in other materials.

"Our discovery was driven in large part by curiosity," said former School of Physics graduate student **Xiaojian Bai**, the research paper's first author. Other Georgia Tech School of Physics-affiliated researchers involved in the study are former Postdoctoral Scholar **Zhiling Dun** (now an engineer for Applied Materials) and Associate Professor **Martin Mourigal**.

Bai earned his Ph.D. at Georgia Tech and has worked as a postdoctoral researcher at ORNL, where he uses neutrons to study magnetic materials. He is now an assistant professor at Louisiana State University. "I came across this iron-iodide material in 2019 as part of my Ph.D. thesis project. I was trying to find compounds with a magnetic triangular lattice arrangement that exhibits what's called 'frustrated magnetism.'"

In common magnets, like refrigerator magnets, the material's electrons are arranged in a line like arrows that either all point in the same direction — up or down — or they alternate between up and down. The directions the electrons point are called 'spins.' But in more complex materials like iron-iodide, the electrons are arranged in a triangular grid, wherein the magnetic forces between the three magnetic moments are conflicted and are unsure of which direction to point — hence, 'frustrated magnetism.'

"As I was reading through all the literature, I noticed this compound, iron-iodide, that was discovered in 1929 and was studied somewhat intensively back in the 1970s and '80s," said Bai. "At the time, they saw some peculiarity, or unconventional modes of behavior, but they didn't really have the resources to fully understand why they were seeing it. So, we knew there was something unsolved that was strange and interesting, and compared to forty years ago, we have much more powerful experimental tools available, so we decided to revisit this problem and hoped to provide some new insights."

Quantum materials are often described as systems that exhibit exotic behavior and disobey classical laws of physics — like a solid material that behaves like a liquid, with particles that move like water and refuse to freeze or stop their motion even at freezing temperatures. Understanding how those exotic phenomena work, or their underlying mechanisms, is the key to advancing electronics and developing other next-generation technologies.

"In quantum materials, two things are of great interest: phases of matter such as liquids, solids, and gases, and excitations of those phases, like sound waves. Similarly, spin waves are excitations of a magnetic solid material," said Mourigal, of the School of Physics. "For a long time, our quest in quantum materials has been to find exotic phases, but the question we asked ourselves in this research is 'Maybe the phase itself is not apparently exotic, but what if its excitations are?' And indeed that's what we found."

> *"We knew there was something unsolved that was strange and interesting, and compared to forty years ago, we have much more powerful experimental tools available, so we decided to revisit this problem and hoped to provide some new insights."*
>
> *Xiaojian Bai, Louisiana State University*

Neutrons are ideal probes to study magnetism because they themselves act like microscopic magnets and can be used to interact with and excite other magnetic particles without compromising a material's atomic structure.

Bai was introduced to neutrons when he was a graduate student of Mourigal's at Georgia Tech. Mourigal has been a frequent neutron scattering user at ORNL's High Flux Isotope Reactor (HFIR) and Spallation Neutron Source (SNS) for several years, using the DOE Office of Science facilities to study a wide range of quantum materials and their various and bizarre behaviors.

When Bai and Mourigal exposed the iron-iodide material to a beam of neutrons, they expected to see one particular excitation or band of energy associated with a magnetic moment from a single electron; but instead they saw not one, but two different quantum fluctuations emanating simultaneously.

"Neutrons allowed us to see this hidden fluctuation very clearly and we could measure its entire excitation spectrum, but we still didn't understand why we were seeing such abnormal behavior in an apparently classical phase," said Bai.

For answers, they turned to theoretical physicist **Cristian Batista**, Lincoln Chair Professor at the University of Tennessee–Knoxville, and deputy director of ORNL's Shull Wollan Center. With help from Batista and his group, the team was able to mathematically model the behavior of the mysterious quantum fluctuation and, after performing additional neutron experiments using the CORELLI and SEQUOIA instruments at SNS, they were able to identify the mechanism that was causing it to appear.

"In a sense, we're looking for dark particles," Batista added. "We can't see them, but we know they're there because we can see their effects, or the interactions they're having with the particles that we can see."

Mourigal likened the way neutrons detect particles to waves breaking around rocks on the ocean's surface.

"In still water we can't see the rocks at the bottom of the ocean until a wave moves over it," Mourigal said. "It was only by creating as many waves as possible with neutrons that, through Cristian's theory, Xiaojian was able to identify the rocks, or in this case, the interactions that make the hidden fluctuation visible."

Harnessing quantum magnetic behavior has already led to technological advances such as the MRI machine and magnetic hard disc storage that catalyzed personal computing. More exotic quantum materials may expedite the next technological wave. • JEREMY RUMSEY

A small sample of iron-iodide is mounted and prepared for neutron scattering experiments which were used to measure the material's fundamental magnetic excitations. ORNL, GENEVIEVE MARTIN

The Geometries of Chaos

Researchers develop methodology for streamlined control of material deformation

Can you crumple up two sheets of paper the exact same way? Probably not — the very flexibility that lets flexible structures from paper to biopolymers and membranes undergo many types of large deformations makes them notoriously difficult to control.

Researchers from Georgia Tech, Universiteit van Amsterdam, and Universiteit Leiden have shed new light on this fundamental challenge, demonstrating that new physical theories provide precise predictions of the deformations of certain structures. The end result could redefine the term non-invasive surgeries by allowing doctors to use tiny "soft" robots inside the human body.

The Georgia Tech contingent of the research team is from the School of Physics: former Postdoctoral Scholar **Michael Czajkowsk**i and Assistant Professor **Zeb Rocklin**. They approach a highly studied exotic elastic material, uncover an intuitive geometrical description of the pronounced — or nonlinear — soft deformations, and show how to activate these deformations on-demand with minimal inputs.

This new theory reveals that a flexible mechanical structure is governed by some of the same math as electromagnetic waves, phase transitions, and even black holes.

"So many other systems struggle with how to be strong and solid in some ways but flexible and compliant in others, from the human body and microorganisms to clothing and industrial robots," said Rocklin. "These structures solve that problem in an incredibly elegant way that permits a single folding mechanism to generate a wide family of deformations. We've shown that a single folding mode can transform a structure into an infinite family of shapes."

Top: A conformal deformation of the Kagome Metamaterial gives an example of dramatic possibilities.

A brief history of metamaterials

Metamaterials rely on the use of hinges, folds, cuts, and "flexible" ingredients to display the variety of counterintuitive physics that has been steadily revealed over the past decade of intense research. Many of these new behaviors have emerged from the development of auxetics, materials that tend to shrink in all directions when they are compressed from any direction rather than bulging outward. Although the researchers' chosen structure, "Rotating Squares," is already one of the most heavily researched metamaterials, they uncovered entirely new and powerful physics hiding within its deformations.

"Normally complex real-world structures defy analytical physics, which made it all the more thrilling when Michael found that his conformal predictions could account for 99.9 percent of the variance in Corentin's structure," said Rocklin. "This new approach could allow us to predict and control tough, flexible structures from the size of skyscrapers to the microscale."

> ***"This new approach could allow us to predict and control tough, flexible structures from the size of skyscrapers to the microscale."***
>
> *Zeb Rocklin, School of Physics*

Conformal findings

The results of this paper rely on the novel observation that these maximally auxetic metamaterials deform conformally, which the researchers confirmed with a high degree of accuracy. This means that any angle drawn on the material before and after deformation will still look like the same angle. This seemingly mundane observation activates powerful mathematical structures.

This conformal insight allows for a variety of pen-and-paper analytic advances: a nonlinear energy functional, deformation fitting methods, new prediction methods, etc. This culminates with a recipe to choose any of these conformal deformations in an exact, reversible, and mathematically straightforward manner via the manipulation of the boundary. By choosing how much the boundary is stretched, the overall shape can be picked from infinite possibilities.

Such deformation control is still limited by the essential nature of conformal deformations. However, the underlying principles are quite general, and researchers are working to apply these new principles to more varied and complex structures.

"Our results are very promising for the soft microscopic robotics that are being developed for non-invasive surgical purposes," said Czajkowski. "In this effort, scalability and precise external control are two of the primary goalposts, and our style of deformation control seems perfectly suited for the job."

The jump to more provocative applications is likely not far off, as the realm of metamaterials has steadily become populated with manipulatable faces, a variety of new grabbers and hands, and even an elastic worm that can thread a series of needles. These advances will become essential in the effort to develop soft microscopic robots, which must be externally manipulated to move through a body and perform noninvasive surgeries. • GEORGIA ROBERT PARMELEE

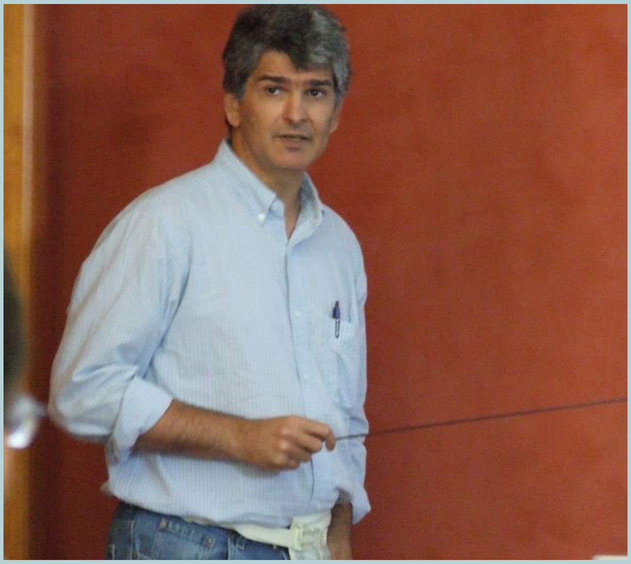


PHOTO: SCIENTIFIC COMPUTING LABORATORY AT THE INSTITUTE OF PHYSICS BELGRADE

Carlos A. R. Sa de Melo Selected as New AAAS Fellow

School of Physics Professor **Carlos A. R. Sa de Melo** was selected to join the 2021 class of fellows of The American Association for the Advancement of Science (AAAS), one of the highest distinctions in the scientific community.

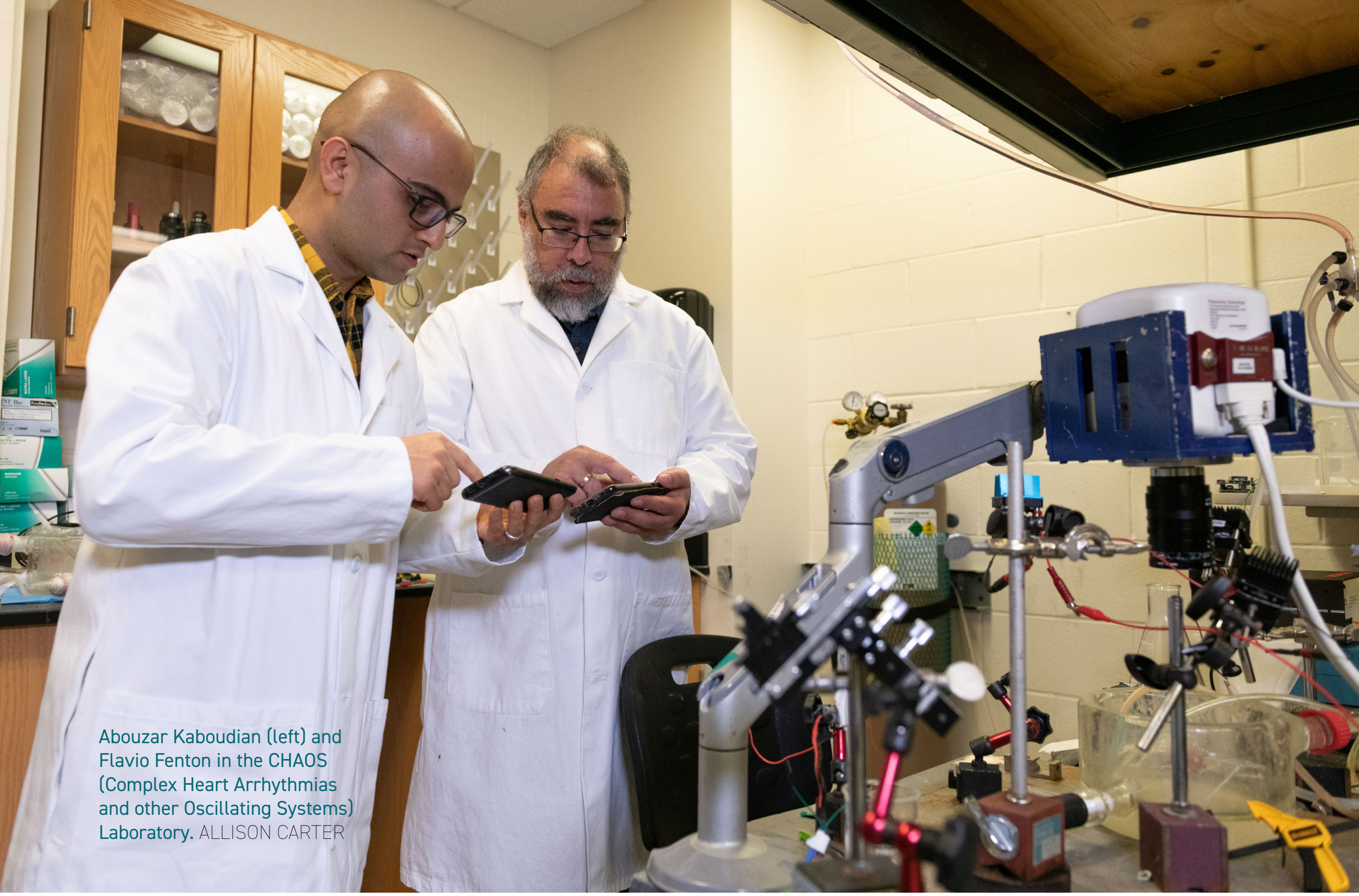
The class includes 564 scientists, engineers, and innovators spanning 24 scientific disciplines who were recognized for their scientifically and socially distinguished achievements. **Kim M. Cobb**, former ADVANCE Professor in the School of Earth and Atmospheric Sciences and current director of the Institute at Brown for Environment and Society; and **Hanjoong Jo**, Wallace H. Coulter Distinguished Faculty Chair in Biomedical Engineering and the Coulter Department of Biomedical Engineering's associate chair for Emory University, also joined the 2021 class of Fellows.

Sa de Melo was selected for his seminal contributions to superconductivity and superfluidity, particularly the crossover from BCS (Bardeen–Cooper–Schrieffer) superconductivity to Bose-Einstein condensation in ultra-cold atoms, and for communicating these advances to students and the public.

His work focuses on theoretical condensed matter and ultra-cold atomic and molecular physics: superconductors, quantum magnets, superfluids, and Bose-Einstein condensates.

"I strongly encourage my students to be broad, deep and creative," he said. "Breadth of knowledge is very important in today's physics job market, as is expert (deep) knowledge in a particular area." But most of all, he added, it's "the development of new directions, never explored before" comprising the dominant component of his research.

"I am very thankful to the colleagues that have nominated me for such a recognition — to my students and postdocs for their collaboration," Sa de Melo said, "and to the AAAS Council for electing me to the rank of Fellow for contributions to theoretical physics in the fields of superconductivity and superfluidity." • JESS HUNT-RALSTON



Abouzar Kaboudian (left) and Flavio Fenton in the CHAOS (Complex Heart Arrhythmias and other Oscillating Systems) Laboratory. ALLISON CARTER

Spiral Wave Teleportation Theory Offers New Path to Defibrillate Hearts, Terminate Arrhythmias

A spiral wave of electrical activity in the heart can cause catastrophic consequences. One spiral wave creates tachycardia — a heart rate that's too fast — and multiple spirals cause a state of disorganized contraction known as fibrillation. Researchers from Georgia Tech offer a new method to disrupt spiral waves that uses less energy and that may be less painful than traditional defibrillation.

This research has been ongoing in School of Physics Professor **Flavio Fenton**'s lab with his student **Noah DeTal** and research scientist **Abouzar Kaboudian**. Their recent findings were published in the paper, "Terminating Spiral Waves with a Single Designed Stimulus: Teleportation as the Mechanism for Defibrillation," in the journal *Proceedings of the National Academy of Sciences*.

The problem with spiral waves

Electrical waves enable the heart to contract and send blood throughout the body. When a wave becomes a spiral, its rotation is faster than the heart's natural pacemaker and suppresses normal cardiac function. Instead, one spiral wave can spawn more spirals until the heart is overtaken by multiple spiral waves, leading to disorganized contraction, and preventing the heart from supplying the body with blood.

For years, scientists and doctors have worked to find the best way to stop spiral waves before they get out of control. Yet for over half a century the best method has been a single strong electric shock. The 300 joules of energy required for defibrillation excites not just the heart cells, but the entire body, making it very painful for the patient. Over the years researchers have experimented with using weaker shocks to reorganize arrhythmias.

"We still did not have a clear understanding of how defibrillation worked," said Fenton. "This research

"We still did not have a clear understanding of how defibrillation worked. This research explains the minimum energy required to actually terminate an arrhythmia and I believe it clarifies the mechanism for defibrillation."

Flavio Fenton, School of Physics

explains the minimum energy required to actually terminate an arrhythmia and I believe it clarifies the mechanism for defibrillation."

The symmetrical solution

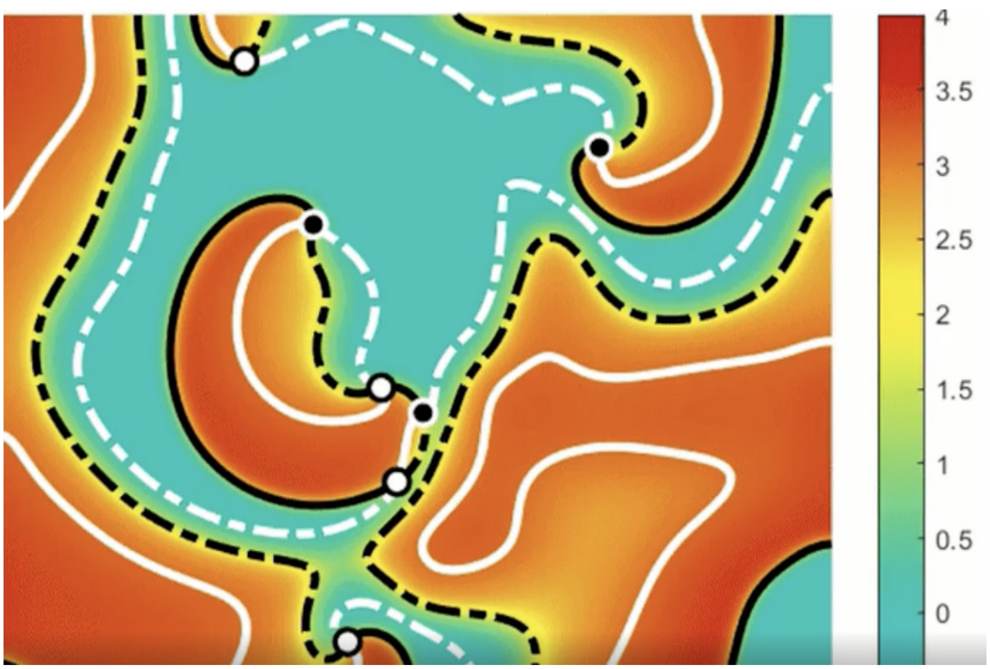
The researchers determined that because spiral waves develop in pairs, they must also be terminated in pairs. Every spiral wave is connected to another spiral going in the opposite direction. Bringing the spiral waves together through an electric shock instantly eliminates both waves.

The researchers used a mathematical method to identify the key regions for electrical shock stimulation to target spiral waves. They determined that a stimulus delivered to the tissue areas a spiral wave just left and were able sustain a new wave could defibrillate the heart.

In the process of terminating the spiral waves, the researchers were actually moving them, as well, through a concept they named teleportation. "We call it teleportation because it's very similar to what you see in science fiction where something is moved instantaneously from one place to another," Fenton said.

Spiral waves can be teleported anywhere in the heart using this approach. In particular, spiral waves can be moved so that they collide with their partners, which extinguishes them. Fenton explained that for successful defibrillation to occur, all pairs of spiral waves must be eliminated in this manner.

The researchers plan to further test this concept using two-dimensional cultures of heart cells. "The next step is to prove experimentally that what we did numerically is possible," Fenton said. Eventually, Fenton added, they want to develop methods that could be used clinically, and are partnering with cardiologists at Emory University on this work. • TESS MALONE



Example of instantaneous termination of fibrillation (multiple spiral waves) by the designed stimulus that teleports all spiral wave pairs to annihilation. FLAVIO FENTON LAB

Progress *and* Service

for all *— at* ***Georgia Tech*** *and* ***beyond***

PHOTO: RAFTERMEN PHOTOGRAPHY

Little Einsteins Organization Brings Science and Engineering to Kids

The past two years have presented many challenges for those involved in education, but that hasn't stopped Georgia Tech's Little Einsteins Organization (LEO) from helping provide students in K-5 schools with instruction and activities focused on STEM.

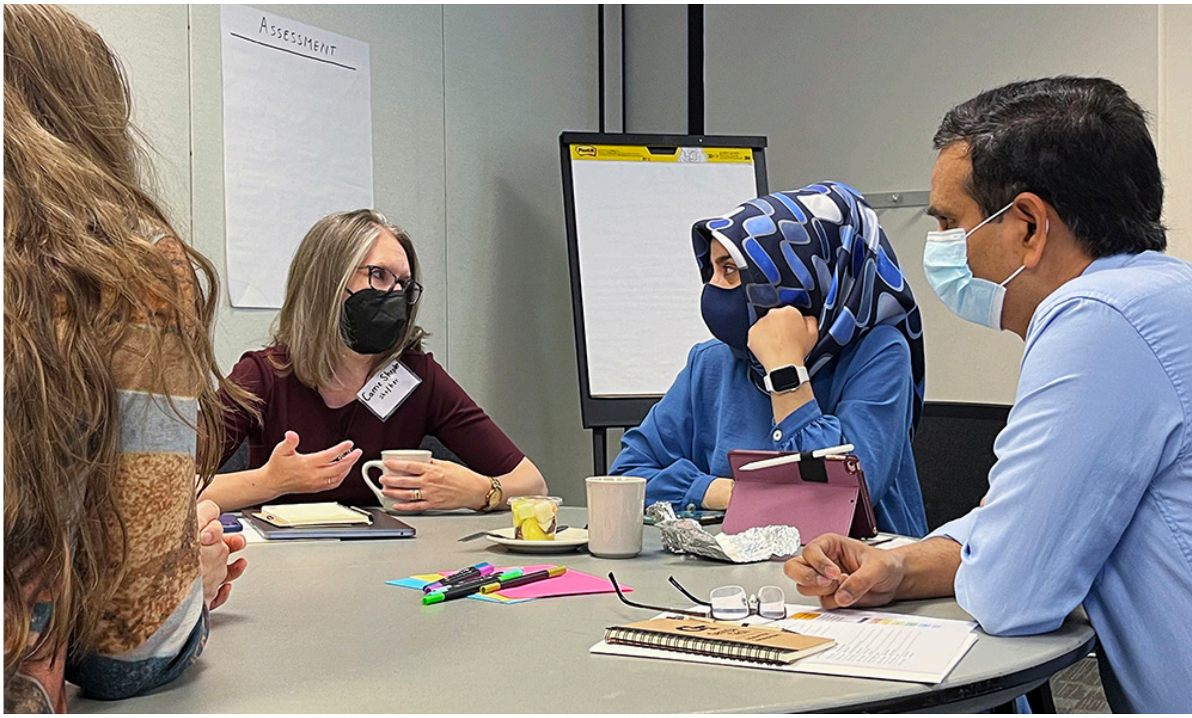
They've accomplished that by changing how they bring science and engineering to the kids — either in their homes, or masked and socially distanced in libraries — where children could perform experiments found in do-it-yourself kits assembled by Georgia Tech volunteers.

"This project is unique because it gives Georgia Tech students the opportunity to support the education of young children in Atlanta during a time of isolation and online schooling," said **Pamela Pollet**, the group's academic advisor. "It demystified the image given to a scientist or engineer."

"The young students had the opportunity to ask questions, and Georgia Tech students were able to encourage the younger students and see the impact of the kits they had provided," said **Olivia Gravina**, former LEO President and a newly minted alumna of the School of Mathematics.

Pollet said the ability to show younger students that they could eventually pursue science careers is critical, pandemic or no pandemic. "Being virtual all day [left] many of them disconnected from the material and what science is about: experiments, observations, questions, analysis," Pollet said. "Young, dynamic Tech students who are doing science, and taking the time to do it with them," Pollet said. "That is really inspiring." • RENAY SAN MIGUEL

> “One of our ultimate goals was to develop a community of faculty who are dedicated to intentional inclusion in their teaching spaces.
>
> ***Kate Williams**, Assistant Director of Teaching Assistant (TA) Development and Future Faculty Initiatives, Center for Teaching and Learning*



Inclusive STEM Teaching Fellows Program Highlights Commitment to Inclusion and Innovation

An integral part of Georgia Tech's new Diversity, Equity, and Inclusion Plan is the Institute's commitment to supporting innovative and inclusive scholarship and teaching. The Inclusive STEM Teaching Fellows Program, a collaborative partnership between the College of Sciences, College of Engineering, the College of Computing, the Center for Teaching and Learning, and Institute Diversity, Equity, and Inclusion is poised to help accomplish that goal.

In its inaugural year, 19 faculty members completed the Inclusive STEM Teaching Fellows program, which aimed to provide a space for Georgia Tech faculty who are interested in increasing inclusivity in their teaching and learning communities to collaborate, learn, grow, and develop community. Participants completed the five-week Inclusive STEM Teaching Project massive online open course provided by the National Science Foundation (NSF). The course explores power, privilege, and positionality; instructor and student identity; and inclusive course design and implementation practices. The Inclusive STEM Teaching Fellows Program culminated in a two-day institute this past May, where participants and a group of nine facilitators discussed how to put the practices they learned about into action.

"The NSF's STEM Teaching Project strongly encourages participation in learning communities while completing the asynchronous course," said **Jennifer Leavey**, assistant dean for Faculty Mentoring in the College of Sciences. "We wanted to put a spin on that idea. Rather than running a learning community in conjunction with the online course, we opted to host a two-day intensive, during which participants could dig into the details of the material and share ideas and experiences."

Six faculty members from the College of Sciences and the Center for Teaching and Learning completed facilitator training and hosted two pilot synchronous learning communities in summer and fall 2021.

"We proposed the institute as a way to help faculty carve out dedicated time to focus on the concepts covered in the online course and better understand how to put them into practice," said **Carrie Shepler**, Assistant Dean for Teaching Effectiveness in the College of Sciences. "Having two days to delve into the material and focus on application provided a huge advantage to our participants, and ourselves."

Participants expressed a clear desire for continued access to resources during the institute, according to **Kate Williams**, assistant director of Teaching Assistant Development and Future Faculty Initiatives with the Center for Teaching and Learning at Georgia Tech.

"One of our ultimate goals was to develop a community of faculty who are dedicated to intentional inclusion in their teaching spaces," Williams said. "We noticed that participants specifically were interested in understanding how their peers — teaching similar classes and facing the same barriers to creating inclusive learning spaces — navigate those challenges."

"Programs such as these — in which faculty come together in community to question, learn, and reflect on how to make their teaching more inclusive and their classrooms more welcoming and equitable for all students — are critical to achieving the cultural transformations we are seeking for teaching, research, and scholarship at Georgia Tech," said **Diley Hernández**, associate vice president for Institute Diversity, Equity, and Inclusion (IDEI) at Georgia Tech. "My hope is that the conversations and experiences shared in this program will continue among faculty as we grow this community and continue to tackle these important issues."

The program was funded through the Howard Hughes Medical Institute's Inclusive Excellence 3 Community Cluster grant, secured by the College of Sciences, with additional support provided by the College of Engineering and the College of Computing.
• TAMMY PARRETT

Assistant dean for Teaching Effectiveness Carrie Shepler (left) shares in an Inclusive STEM Teaching discussion.

"

Programs such as these — in which faculty come together in community to question, learn, and reflect on how to make their teaching more inclusive and their classrooms more welcoming and equitable for all students — are critical to achieving the cultural transformations we are seeking for teaching, research, and scholarship at Georgia Tech.

***Diley Hernández**, Associate Vice President for Institute Diversity, Equity, and Inclusion*

Kelly Sepcic Pfeil (top) and Raquel Lieberman.

Alumna-Endowed Chair Paves Path for More Women Faculty in STEM

School of Chemistry and Biochemistry Professor **Raquel Lieberman** is the inaugural chair of the **Kelly Sepcic Pfeil**, Ph.D. Faculty Endowment Fund, a new effort designed to increase the number of women faculty across the field.

“Pfeil is one of our most successful Ph.D. graduates,” Lieberman said. “She attended graduate school at a time when there were far fewer female students, and no tenured female faculty members. Her decision to endow this position is terrific, and it expands upon involvement to tangibly improve the camaraderie and peer mentorship of female graduate students in our department.”

A College of Sciences Advisory Board member, Pfeil received her M.S. in Chemistry in 1992 and her Ph.D. in the same discipline in 2003. She and her husband **David** established the fund to counter statistics showing less than 20 percent of STEM faculty positions nationwide are held by women — with most of those assistant professor positions, considered a launch point for academic careers, and many of those women eventually choosing to leave academia and enter the private sector.

“Students need more role models,” Pfeil said. “If young women and minority students don’t see more women in faculty positions, they may be discouraged from obtaining STEM degrees. That could lead to even fewer women in these disciplines. We are building a pipeline for women in STEM, and that pipeline starts in academia.” • RENAY SAN MIGUEL

“

We are building a pipeline for women in STEM, and that pipeline starts in academia.

Kelly Sepcic Pfeil, College of Sciences Advisory Board Member

Georgia Tech-Lorraine Joins NeurotechEU as Founding Partner

For over 30 years, Georgia Tech-Lorraine has led the European presence in Georgia Tech's commitment to excellence in academics, research, and innovation. Now, the campus has joined a network of universities and partners throughout Europe with these goals.

Georgia Tech's Metz, France campus is the newest full partner of The European University of Brain and Technology, NeurotechEU, joining eight elite European universities including the University of Oxford and the Karolinska Institute.

Above: Georgia Tech-Lorraine. Below: Celebrating the signing of Georgia Tech-Lorraine into NeurotechEU. UNIVERSITY OF BONN

Combined with over 250 industry partners and funded by the European Commission, NeurotechEU is creating "a trans-European network of excellence in brain research and technologies" to increase competitiveness in education, research, economy, and society.

"Georgia Tech-Lorraine's Institut Lafayette has the equipment, facilities, and infrastructure to contribute uniquely," said **Tansu Celikel**, chair of NeurotechEU's Board of Governors and chair of the School of Psychology at Georgia Tech. "This partnership is poised to advance the state of art in medical technologies."

The partnership will also focus on educational effort and on Georgia Tech – CNRS IRL 2958, an international research laboratory with the Centre National de la Recherche Scientifique that is focused on nine areas of work, from smart materials and secure networks research to aerospace and robotics.

"It's just the beginning, especially for our students," said Georgia Tech-Lorraine President **Abdallah Ougazzaden**. "We can contribute to this field that is also related to challenges for our society ... All the problems related to the brain — that's something that we're proud to be involved in." • AUDRA DAVIDSON

In October 2022, Georgia Tech-Lorraine, the Institute's first international campus, officially rebranded as Georgia Tech-Europe. The change reflects the growth of the Institute's presence in Europe and aligns with its strategic goals to amplify impact, champion innovation, connect globally, and expand access.

Tech’s Fossil Hunters

Citizen scientists are welcome during Fossil Fridays on campus

Eleven-year-old Matthew and his brother Joey, age 7, are hunched over a small pile of dirt in Tech’s Spatial Ecology and Paleontology Lab. The brothers aren’t students at Georgia Tech — at least not yet, says their mother, **Christine Conwell**, Ph.D. CHEM ‘04, who works at Georgia Tech and is married to fellow Yellow Jacket **David Gaul**, Ph.D. CHEM ‘98.

Nevertheless, the two young fossil hunters are doing important work for the lab: helping researchers find fossilized bones, some of which could be 30,000 years old. Matthew and Joey are just two of the citizen scientists who have lent a hand during “Fossil Fridays,” an open, two-hour session when members of the community can come learn about paleontology and dig through dirt samples in search of real fossils.

“We’re interested in ‘citizen science’ and making sure our community knows what we’re working on and feels included,” said **Julia Schap**, a fourth-year Ph.D. candidate and one of the hosts of Fossil Fridays. “We don’t like this idea that science happens behind closed doors.”

The program started in 2014 as a hands-on community activity, but also, partly, as a much-needed solution to help researchers in **Jenny McGuire**’s Spatial Ecology & Paleontology Lab at Georgia Tech sift through literally a ton of dirt pulled from the Natural Trap Cave in Wyoming.

As the name implies, the cave’s unique geography has made it an ideal spot for paleontologists — a large hole in a plateau above the cave acts as a natural trap. For tens of thousands of years, animals have fallen through the hole to an 80-foot drop below, Schap explained. The stack of bones below the hole is a treasure trove for researchers like Schap. She visited the cave with McGuire summer 2021, and their team bagged and shipped 2,000 pounds of sediment back to Atlanta.

Some of the fossils found in the samples come from rodents, rabbits, lizards, snakes, birds, frogs, and occasionally fish that get brought in by the birds. “A lot of Tech students like Fossil Fridays, especially those who are interested in medical school, because they become more familiar with what animal bones look like compared to humans,” Schap said. “Also, people think it’s just fascinating that you can touch fossils.”

The lab uses fossils in a variety of research areas. Schap studies fossils of small mammals to find out how these species were affected by climate at different periods of history. Her findings are useful for current conservation efforts.

Fossil Fridays have resumed for the fall semester. During a typical session, Schap likes to play movie soundtracks in the background to help fossil hunters unwind. “I sometimes play the *Jurassic Park* soundtrack to really help everyone get in the mood and to feel like they’re doing really important work — because they are.

• JENNIFER HERSEIM

Jenny McGuire, originator and one of the hosts of Fossil Fridays.

“

We’re interested in ‘citizen science’ and making sure our community knows what we’re working on and feels included. We don’t like this idea that science happens behind closed doors.

Julia Schap, School of Biological Sciences

Transforming Tomorrow

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To support Georgia Tech's students, faculty, and staff by expanding opportunities for personal growth, well-being, and holistic learning — through athletics, study abroad, leadership initiatives, and an inclusive, accessible campus.

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External Advisory Board

The College of Sciences External Advisory Board provides advice to the Dean regarding priorities and directions for sciences education and research. Board members are from the private and public sectors and academia, and include alumni who are interested in the success of the College and Georgia Tech.

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Inside the Edge

Boosting Coral Diversity

A study from two School of Biological Sciences researchers provides both hope and a potentially difficult future for damaged coral reefs. In their research paper, "Biodiversity has a positive but saturating effect on imperiled coral reefs," published in *Science Advances*, **Cody Clements** (pictured, cover) and **Mark Hay** found that increasing coral richness — by 'outplanting' a diverse group of coral species together — improves coral growth and survivorship.

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