APS News

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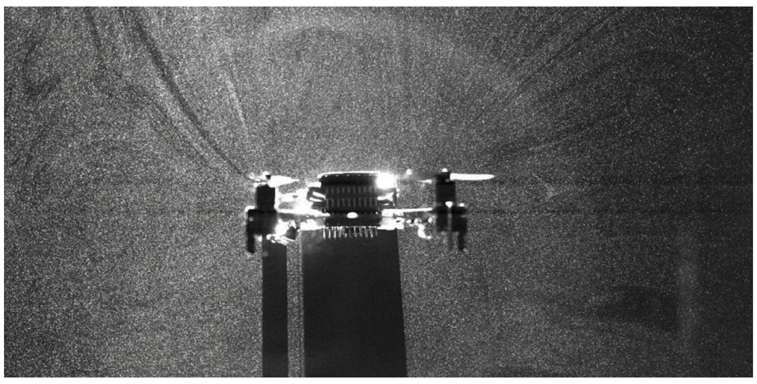
Drones Blowing, and Flying, In The Wind

At an APS fluid dynamics meeting, researchers showed off new robotic technologies for studying atmospheric pollution.

BY SOPHIA CHEN



"LaDrone," a micro aerial vehicle designed by a Princeton team, hovering in a laser-illuminated particle field. Credit: Girguis Sedky

It can be a tough act, delivering a talk at the end of the day at a conference. But Nate Simon brought a tiny drone to entertain the audience. Resembling a flying crab and about the weight of a plum, the robot rose into the air and meandered across the room before Simon, a fourth-year robotics graduate student at Princeton University, let it plummet to the ground. The audience laughed.

In recent years, researchers like Simon have begun developing drones to study matter in the atmosphere. "People are interested in understanding the flow," says Simon, who presented his work in Washington, DC, at this November's annual meeting of APS's Division of Fluid Dynamics. "That could be to track pollutants, how wildfire smoke disperses, or understanding how mosquitoes fly and find humans."

Visualizing and measuring fluid flow isn't new: Aerospace engineers have long done so by blowing smoke into wind tunnels. But these are idealized environments. The challenge is making the same measurements in chaotic real-world environments, says Jiarong Hong of the University of Minnesota, who also presented at the conference. "In a wind tunnel, you know the wind speed," says Hong. "But in field experiments, there are a lot of factors you can't control. The wind changes. There are gusts."

Hong's team has developed a fleet of four drones that use a sensor that acts like a 3D microscope, along with computer vision, a type of artificial intelligence, to track the flow of wildfire smoke. After testing the drones' ability to detect smoke in a computer simulation, Hong's team began field experiments. They flew the drones through smoke generated from a smoke machine and smoke grenade.

The drones coordinate with each other to capture microscopic images of particles, from which Hong can derive the smoke particle size,

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At Nobel Lectures, Laureates Discuss Work Illuminating Electrons

The physics laureates shared their stories with the public in Stockholm.

BY ABIGAIL DOVE

The 2023 Nobel laureates in physics (Krausz, L'Huillier, and Agostini) after their lectures on Dec. 8 at Stockholm University. Credit: © Nobel Prize Outreach / Photo: Nanaka Adachi

The Nobel Prize is one of science's most prestigious honors, recognizing individuals who have "conferred the greatest benefit to humankind." The prize's founder, Alfred Nobel, was born in Sweden's capital, Stockholm, which today is the epicenter of Nobel Prize festivities and the site of the secretive committees that select the prizewinners.

But while the Nobel Prize Ceremony is a closed-door affair, members of the public can join the festivities by attending the Nobel lectures, where the laureates speak. The event is free to anyone, provided they line up early enough in Stockholm's famously cold winter weather.

The 2023 Nobel Prize in Physics was awarded for the development of techniques to produce pulses of light so brief that they are measured in "attoseconds" (10^{-18} seconds, or a billionth of a nanosecond), thus enabling the study of the ultra-fast movement of electrons inside atoms and molecules.

Even in a field famous for probing the extremely large and the ex-

Nobel Lectures continued on page 5

Young-Kee Kim, 2024 APS President, on Partnerships at Home and Abroad

An interview with Kim, an experimental physicist with big plans for APS.

BY TARYN MACKINNEY

Young-Kee Kim

For Young-Kee Kim, physics has always transcended borders.

"Global collaboration isn't only a necessity," she says. "There's also beauty in it."

Kim is the 2024 APS President and an experimental particle physicist, whose field is known for projects of grandiose scale, with thousands of scientists around the world working in tandem on decades-long projects.

"There are so many wonderful outcomes, because we have so many people from diverse backgrounds," she says.

Kim herself is a walking example of global science: Originally from South Korea, she has worked on experiments in Japan, Switzerland, and the U.S.

Kim earned her bachelor's and master's degrees in physics from Korea University and her doctorate from the University of Rochester, and worked at Lawrence Berkeley National Laboratory as a postdoctoral fellow. After several years at the University of California, Berkeley, she moved to the University of Chicago in 2003, where she is the Louis Block Distinguished Service Professor of physics.

For decades, she has sought to understand the nature of fundamental particles. "I'm interested in

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At Green Bank Observatory in West Virginia, Life is Radio Silent — by Design

APS's newest Historic Site celebrates 65 years since its first radio telescope came online.

BY KENDRA REDMOND

The Green Bank Observatory (GBO) is home to the largest moveable object on land that humans have ever built — a radio telescope. It's also home to countless juxtapositions.

Surrounded by mountains and in the middle of two radio quiet zones, GBO lacks Wi-Fi, Bluetooth, and reliable cellular service — but even as it seeks to quiet modern technology, the observatory relies on it. It boasts the latest receiver technologies, but the data it collects leaves GBO via miles of ethernet cables. Staff can point the telescope at a distant galaxy with the uncertainty of a few arcseconds, but they aren't allowed to heat coffee in a microwave.

The rural environment makes GBO a study in contrasts, too. "You can be in the control room with really state-of-the-art electronics and then take a walk for a break and see a bear," says Felix "Jay" Lockman, a 30-year staff member and former director.

GBO opened in the late 1950s as the National Radio Astronomy Observatory (NRAO). The National Science Foundation selected the rural location in Green Bank, West Virginia, as the valley is naturally shielded from radio emissions by mountains, the climate is dry, and the sparse population of people and cars means lower levels of radio interference.

NRAO's first of many telescopes, an 85-foot dish, started collecting data in early 1959, kicking off 65 years of pioneering discoveries. Among the early projects, Frank Drake mapped the radio sources at

GBO's Green Bank Telescope. Credit: NSF/GBO/Jill Malusky

the center of the Milky Way Galaxy and conducted the first modern systematic search for signs of extraterrestrial life (Project Ozma). Since then, scientists have used GBO data to spot dark matter halos around galaxies, discover new pulsars, identify interstellar molecules and, most recently, detect the signature of background gravitational waves in pulsar timing arrays.

For the last 20 years, the observatory's research heavyweight has been the Robert C. Byrd Green Bank Telescope (GBT), the world's largest fully steerable radio telescope. With a 100-meter dish sensitive to frequencies from 0.1 to 116 GHz, the telescope is helping scientists study the solar system, black holes, gravitational waves, and neutron stars. GBT is also a key instrument for Breakthrough Listen, a SETI project at the University of California, Berkeley, using radio telescopes to search for signs of intelligence.

The observatory was renamed GBO after being spun off from other NRAO sites in 2016. And in September 2023, APS designated Green Bank an APS Historic Site, an acknowledgement of the observatory's importance to physics history.

Keeping radio interference levels low over 65 years of technological advances has required commitment and creativity. "Anything that can create a spark can cause us interference, so things like heaters, pumps, power lines, and cars with spark plugs can be a problem," says Chuck Niday, a GBO electronics technician whose job includes locating and, if possible, removing radio frequency interference. "Wi-Fi is a huge source of noise," he says.

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Get Ready for APS March Meeting 2024

As APS heads to Minneapolis, physicists can engage in person, online, or at a satellite event abroad.

BY LIZ BOATMAN

Credit: American Physical Society

If you've visited Minneapolis, you might know March is the best month for an authentic "city of lakes" experience — as long as you bring ice skates, or an ice auger and a fishing pole. This year, Minneapolis will welcome APS March Meeting 2024 attendees to the city's convention center from March 3-8. A virtual program will run at the same time.

APS expects 13,000 attendees at the March Meeting in-person and online, surpassing attendance at last year's event, the world's largest physics gathering in 2023.

And 2024 is a big year for another reason: It's APS's 125th anniversary. Meeting Chair Paul Chaikin, a physics professor at New York University, is excited to mark the occasion with meeting attendees, as well as to celebrate the "important discoveries of the past century" and "new fundamental understanding" in the field, he says.

In addition to five days of hundreds of scientific talks spanning the discipline, tailored programming will be offered for students and early career physicists. Meeting highlights include:

Career sessions: Future of Physics Days events will include a grad school fair and workshops on effective networking and job searches, with special meeting grants available for undergrads (apply by Jan 16). This year's Industry Day events include sessions ranging from how to found start-ups to careers in data science. Networking events will also give students a chance to connect with industrial and applied physicists.

Special sessions: Some events will be live-streamed for virtual participants, like the special session featuring Nobel laureates on Sunday, March 3. Pierre Agostini and Ferenc Krausz, two of the three 2023 laureates in physics, as well as one of last year's chemistry winners, Moungi Bawendi, will address attendees. And on Thursday, March 7, the Kavli symposium looks toward the 21st-century challenge of 'Physics Far From Equilibrium', with a speaker lineup that includes Denis Bartolo, Niktra Fakhri, Mikhail Lukin, Chiara Mingarelli, and David Weitz. Their research spans from biophysics to quantum computing. (And there might be chocolate involved.)

Events for the public: Several APS units are teaming up to offer an all-ages Squishy Science Sunday event at the Minneapolis Convention Center, open to the public. Volunteers will deliver hands-on experiments and science demos that explore the world of biophysics, polymers, soft matter, and statistical physics.

Global satellites: Building off last year's successful satellite meetings, Chaikin expects APS will see even greater participation by inter-

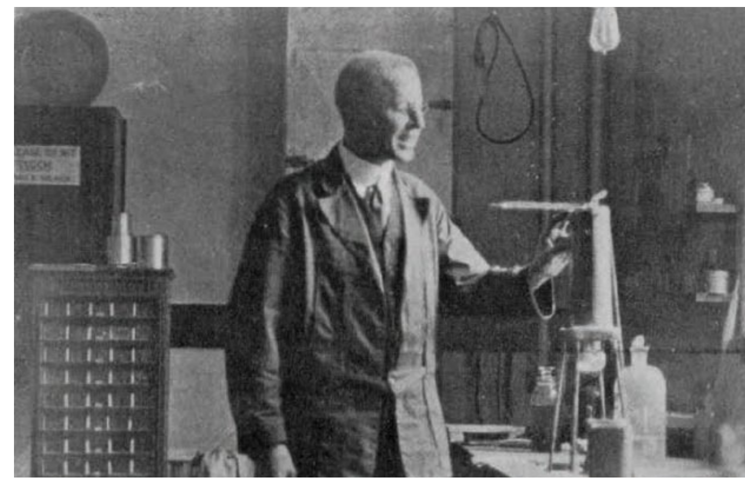
March Meeting continued on page 4

THIS MONTH IN PHYSICS HISTORY

February 1907: Bertram Boltwood Estimates Earth is at Least 2.2 Billion Years Old

Though he was off by over 2 billion years, his method of uranium-lead radiometric dating is still used today.

BY TESS JOOSSE



Bertram Boltwood in his laboratory at Yale in 1917. Credit: Public domain

We take for granted that Earth is very old, almost incomprehensibly so. But for much of human history, estimates of Earth's age were scattershot at best. In February 1907, a chemist named Bertram Boltwood published a paper in the *American Journal of Science* detailing a novel method of dating rocks that would radically change these estimates. In mineral samples gathered from around the globe, he compared lead and uranium levels to determine the minerals' ages. One was a bombshell: A sample of the mineral thorianite from Sri Lanka (known in Boltwood's day as Ceylon) yielded an age of 2.2 billion years, suggesting that Earth must be at least that old as well. While Boltwood was off by more than 2 billion years (Earth is now estimated to be about 4.5 billion years old), his method undergirds one of today's best-known radiometric dating techniques.

In the Christian world, Biblical cosmology placed Earth's age at around 6,000 years, but fossil and geology discoveries began to upend this idea in the 1700s. In 1862, physicist William Thomson, better known as Lord Kelvin, used Earth's supposed rate of cooling and the assumption that it had started out hot and molten to estimate that it had formed between 20 and 400 million years ago. He later whittled that down to 20-40 million years, an estimate that rankled Charles Darwin and other "natural philosophers" who believed life's evolutionary history must be much longer. "Many philosophers are not yet willing to admit that we know enough of the constitution of the universe and of the interior of our globe to speculate with safety on its past duration," Darwin wrote. Geologists also saw this timeframe as much too short to have shaped Earth's many layers.

Lord Kelvin and other physicists continued studies of Earth's heat, but a new concept — radioactivity — was about to topple these pursuits. In the 1890s, Henri Becquerel discovered radioactivity, and the Curies discovered the radioactive elements radium and polonium. Still, wrote physicist Alois F. Kovarik in a 1929 biographical sketch of Boltwood, "Radioactivity at that time was not a science as yet, but merely represented a collection of new facts which showed only little connection with each other."

Then, in 1902, physicist Ernest Rutherford and chemist Frederick Soddy proposed that radioactivity was the transmutation of one element into another, with alpha, beta, or gamma radiation released during this breakdown. They also found that a radioactive element will decay into a different element at a rate determined by a property known as its "half-life" — the time it takes for half of such atoms in a sample to decay.

In 1904, Boltwood sat in the audience for a lecture Rutherford gave at Yale on the dating potential of radioelements. By determining the amount of a radioactive element and its decay end-product in a rock, scientists could calculate the rock's age using the element's known half-life.

Though spectacular, Boltwood's results landed with a muted thud.

Inspired, Boltwood set out to look for the non-radioactive end product of uranium decay. At this time, he was working in his own private laboratory consulting for mining companies, analyzing ore samples and collecting mineral specimens along the way. In all his mineral samples that contained uranium, Boltwood also detected lead. He concluded that lead must be the final product of the uranium series, known to also include radium in an intermediate step.

Rutherford, who was corresponding with Boltwood, endorsed this idea. Based on Rutherford's calculations, uranium decaying to radium, and radium emitting five alpha particles, would produce an element close in atomic weight to lead. "Knowing the rate of disintegration of uranium, it would be possible to calculate the time required for the production of the proportions of lead found in the different minerals, or in other words the ages of the minerals," Boltwood wrote in his *American Journal of Science* paper.

Rutherford's initial calculations were off, and the half-life of radium was revised several times in 1905 and 1906. Boltwood used the latest (but still inaccurate) half-life value of 2,600 years, along with the finding that most rocks contain 380 parts of radium per billion parts of uranium, to deduce that one part of lead forms, per 10 billion parts of uranium in a rock. He put together a formula: A rock's age in years equals 10 billion times its ratio of lead to uranium atoms. He applied it to a cache of mineral samples, including uraninite from Connecticut and the Ceylonese thorianite. The latter yielded the primeval age of 2.2 billion, by far the oldest estimate for Earth's age ever made at the time.

Though spectacular, Boltwood's results landed with a muted thud. Contemporary geologists were reticent to accept radiometric dating. And Boltwood's calculations were indeed incorrect, both because of the erroneous half-life value (it's now known that the longest-lived radium isotope has a half-life of 1,600 years, not 2,600) and because he failed to account for the decay of another radioactive element, thorium, into lead in some minerals that contained both thorium and uranium. He didn't touch the topic again, and after Yale offered him a position as professor and chair of radiochemistry in 1910, Boltwood slowed his research in favor of teaching and directing several college laboratories.

But by the time Kovarik was writing his biographical remembrance of Boltwood in 1929, the consensus was that "Boltwood laid the foundation for the best method we have today in calculating the 'age of the earth.'" Scientists reached today's accepted age, about 4.54 billion years, in part from a meteorite that crashed down to Arizona (assumed to be the same stuff that made the Solar System and Earth) and using the principles of lead dating first established by Boltwood's thorianite.

Tess Joosse is a science writer based in Michigan.

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STEP UP Program Expands Training in New York, Chicago, and Los Angeles

Partnering with local colleges has bolstered program efforts as coordinators plan recruitment for the next cohort.

BY LIZ BOATMAN

Founded in 2017 to increase the number of women pursuing physics degrees in college, STEP UP has "done nothing but grow," says Bree Barnett Dreyfuss, a high school physics educator in California's Bay Area and STEP UP's lead coordinator for teacher training activities.

After an initial round of federal funding, STEP UP — a collaboration between APS, Florida International University, Texas A&M University, and the American Association of Physics Teachers (AAPT) — launched its first training program cycle in 2018. Since then, more than 250 educators have completed "advocate training," needed to implement STEP UP lessons in their classrooms. Now, STEP UP's leaders are focused on enrolling as many of the country's estimated 27,000 physics teachers as possible.

Challenges abound. "The physics teacher community is very isolated," says Praisy Poluan, a high school science teacher in southern California and a new STEP UP teacher training lead. Physics teachers from different schools rarely have chances to interact, which limits word-of-mouth information about STEP UP, even within the same district.

To overcome this, STEP UP submitted a proposal to the Gordon and Betty Moore Foundation in 2022 with a new idea, to concentrate the program's efforts in three major metropolitan areas — New York

STEP UP's New York Regional Coordinator Elissa Levy works with New York's PhysTEC Lead Ghada Nehmeh. Credit: Elissa Levy

City, Chicago, and Los Angeles — in the hopes of reaching a critical mass of STEP UP-trained teachers in a few years.

The Moore Foundation awarded the STEP UP team $3 million in 2022 for the three-year project.

Last year, Barnett Dreyfuss recruited new regional coordinators — three STEP UP-trained educators, one each for New York, Chicago, and Los Angeles — to help enlist and train new cohorts of in-classroom advocates.

Poluan joined as the Los Angeles area coordinator. Kori Bowns-Kamphuis, who teaches in the Chicago Public Schools, is leading work in Chicago's metro area, and Elissa Levy, a former public school teacher in New York City, is coordinating STEP UP's efforts there.

Levy first learned about STEP UP at a STEM educators' workshop, which framed STEP UP as a program not only for educating students, but also for training teachers on how to promote equity in the classroom.

"I loved it," says Levy. "I knew I had to learn more about it." Levy completed STEP UP training in 2020 and taught the program's lessons to her own students the same year.

Bowns-Kamphuis shares the sentiment. "I really would have benefited from receiving the STEP UP lessons when I was a high schooler … to learn more about the scope of careers that physicists go into and the history of women in physics," she says.

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Enrollment in HBCU Physics Programs Has Declined For Years. An APS Site Visit Program Seeks to Help Reverse the Trend.

The pilot program, which leans on APS's EP3 Guide, aims to help HBCUs identify blind spots and create strategic plans.

BY LIZ BOATMAN

When it was launched in 2021, the Effective Practices for Physics (EP3) Guide equipped physics programs with tools to respond to challenges like declining enrollment. But some schools — particularly historically Black colleges and universities (HBCUs), where undergraduate enrollment has suffered disproportionately in recent decades — are under-resourced and have struggled to find time to use the EP3 Guide.

To support HBCUs and the vital role they've long played in graduating Black physicists, the EP3 team launched a pilot site-visit program designed to help departments identify areas for improvement that could boost enrollment and graduation rates.

"We all have blind spots," says Jesús Pando, a physics professor at DePaul University in Chicago who helped develop some of EP3's recommendations and served on a site visit team. "A site visit can be really valuable."

Modeled from existing site visits designed to improve the climate for women in physics, the pilot EP3 program includes a site visit team and subsequent report, a departmental self-study, and a departmental action plan. APS, working alongside HBCU physics department chairs and the APS Committee on Minorities, has led four site visits since 2021 and has three more scheduled for spring 2024.

Padmaja Guggilla, physics chair at Alabama A&M University in Huntsville, says she registered her department's undergraduate program for a site visit because she wanted "to bring our glory back." Within the school's STEM programs, Guggilla says physics used to be the leader. The department still conducts cutting-edge research, but as engineering disciplines have grown, they've attracted many physics-inclined students away.

"Like many HBCUs, we do not have as many students majoring in physics" as there were a decade ago, she says. "We have 24 undergraduate students and 39 graduate students," but the program used to have almost twice as many undergraduates.

Guggilla thought a site visit might help her department identify hidden challenges or develop new strategies. "It's a nationwide problem," she says, but "we wanted to make sure that, if there is anything we could do to improve our numbers, that we know about it."

The experience wasn't easy, she says. The department had to produce a comprehensive self-study, weighing the program's strengths and weaknesses. "We engaged in a lot of self-reflection as a team," she adds. The intensive, two-day site visit provided a wealth of "constructive feedback," validating the program's strengths and offering guidance on how to improve.

Pando was a member of the site visit team that reviewed the Alabama A&M program, and he's deeply aware of the challenges HBCUs face. Without resources to connect to the broader community, he says HBCU physics departments "are often working in isolation, without time to explore best practices, to connect with other colleagues that have expertise in curriculum design, or even for research."

"The site visit can provide knowledge," he says, "as well as ways to solve those problems."

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Young-Kee Kim continued from page 1

how they acquired mass and how their mass values were determined," she says.

Kim spoke with *APS News* about her background and the opportunities ahead during her year as APS President. *This interview has been edited for brevity and clarity.*

What first got you into physics?

I always enjoyed math. When I got to college, I thought I'd major in math. But I became closer to friends interested in physics, and it looked exciting. I thought, "If I don't like physics, I can always come back to math." It was like a trial.

Then, in my junior year, I had an amazing professor who gave lectures on quantum mechanics and modern physics. That's when I thought, "Wow, this is really something I like." I decided to stick to physics.

What big questions are you most hoping physicists can answer in the coming years?

In my own field, particle physics, and in cosmology, there have been many extraordinary developments — for example, the discovery of the Higgs boson and new evidence of dark matter. We've learned so much about neutrino masses, too.

These discoveries have helped us answer questions, but they've also led to a new set of questions. What's the nature of the Higgs boson, and of dark matter? What's driving the acceleration of cosmic expansion?

These questions deal with the nature of the universe at its two extremes, the very large and the very small. They're grand questions, and that's exciting.

You've long been involved in initiatives that support international engagement in physics. Why are you interested in this?

When I was a graduate student, I worked on an experiment at KEK in Japan with about 60 collaborators from four countries. For my second experiment at Fermilab in the U.S., I started with 200 or 300 collaborators and ended up with 600 or 700 collaborators from 15 countries. Now I'm working on an experiment at CERN in Europe that started with 1,000 collaborators, but now has 3,000 collaborators from over 40 countries.

So my own research has helped me realize the importance of collaboration and coordination internationally. Yes, that's the case in physics — in particle physics, for example, we *have* to work together to build big accelerators and detectors. But the world is facing other big challenges that we need global partnerships to solve, like climate change.

What role should physicists play in tackling a global challenge like climate change?

Physicists, for their part, can hone our understanding of physical processes behind climate change. Physicists can also develop technologies to tackle it, with integrity and ethical research. And physicists can do what they've always done — work with scientists across fields to solve problems.

But we won't succeed without excellent communication with the public. We can't lecture or be arrogant; they're as smart as we are. We have to speak truthfully and respectfully about the science we do.

You've been involved for many years in initiatives that support physics education for young people, especially those underrepresented in physics, like women and people of color. Why is this important to you? What is APS doing in this space?

We have a lot of work left to do to make physics more diverse and inclusive, and reaching young people is an important step. I've been involved in Expanding Your Horizon, a program for middle-school girls. APS has excellent programs, like PhysicsQuest.

We need great teachers, too. There's a shortage of high school physics teachers, and a lot of teachers who teach physics don't have physics backgrounds. The PhysTEC program, which APS co-leads, is working to solve this. We're asking, "How can we help physics majors or graduate students understand the career path to becoming high school teachers?"

And students need to know what they can do with physics. Not everybody teaches physics at a university; many more physics majors end up in industry, in the private sector. We should work hard to include that sector in the Society.

What are your priorities for your year as APS president?

One of my priorities is to strengthen our partnerships with physics societies, both nationally and internationally. Nationally, I'm thinking of societies like the National Society of Black Physicists (NSBP), the National Society of Hispanic Physicists (NSHP), and the American Association of Physics Teachers (AAPT), for example. I have a lot to learn from them. That will be my first step.

Internationally, we plan to have summit meetings through the winter and spring with physics societies in the Americas, Asia-Pacific, Europe, the Middle East, and Africa. It's important that these sister societies are equal partners with APS — that we're all working together to address challenges in physics.

To me, the value of these partnerships reflects the value of diversity, equity, and inclusion. It's not just that DEI is the right thing to do; it's also good for physics. We need new perspectives. We need the next generation of physicists from around the world, from every background and community, to feel like they belong.

What else will APS leadership focus on?

The last APS Strategic Plan came out in 2019. In the last year, while I've been president-elect, I've been working with a group of APS members and staff to refresh that strategy and our vision, mission, and core values. We're going to roll this out in May, on the day of APS's 125th anniversary. It's exciting.

Taryn MacKinney is the Editor of APS News.

FYI Science Policy Highlights

BY THE FYI TEAM

House committee proposes export controls on fundamental research

Michael McCaul (R-TX), who chairs the House Foreign Affairs Committee, released a report in December that calls for the U.S. to revisit its stance of generally exempting fundamental research from export controls. The report recommends the Biden administration revise the presidential policy on research classification to "address China's acquisition of critical technology and know-how through fundamental research." It argues that when the policy was created in the 1980s, the Soviet Union could gain relatively little military value from fundamental research, but the term now includes applied research that is of significant military and economic value to China. The report also asserts the exemption is inconsistently applied and enables "more expansive cross-border engagements over which the U.S. government writ large lacks visibility."

Rep. Michael McCaul (R-TX) holds a report he authored recommending an overhaul of the U.S. export control system. Credit: House Foreign Affairs Committee

Bill to expand foreign funding disclosures for researchers heads to Senate

The House passed a bill in December that would expand disclosure requirements for universities and individual researchers receiving gifts or contracts from foreign sources. The Republican-authored bill passed by a vote of 246-170, with 31 Democrats joining in support. The Defending Education Transparency and Ending Rogue Regimes Engaging in Nefarious Transactions (DETERRENT) Act, if passed by the Senate, would lower the current reporting threshold from $250,000 to $50,000 for funding from most countries, with a $0 threshold for "countries of concern," like China, Russia, and Iran. The legislation would also create new reporting requirements for gifts and contracts awarded to individual researchers at higher education institutions that receive more than $50 million annually in R&D funds, and it would require institutions to receive a waiver to pursue contracts with countries or entities of concern. On a party-line vote, the House rejected an alternative framework proposed by Democrats that would set the threshold at $100,000 for all countries and omit country-specific restrictions.

U.S. rolls out GHG monitoring center and fusion strategy at UN climate conference

At the latest UN Climate Change Conference, known as COP28, NASA unveiled the U.S. Greenhouse Gas Center, an interagency hub that will host a catalog of satellite, airborne, and ground-based observations and will estimate emissions from human activities and natural sources. The center is a cornerstone of the national greenhouse gas monitoring system outlined in a report released in November by the White House. The report recommends beginning with two urban-scale prototype monitoring systems covering Washington, D.C., and Indianapolis, Indiana. Separately at the conference, the U.S. outlined an international strategy for accelerating development of fusion power systems, calling for new multilateral R&D partnerships, the development of global fusion supply chains, and coordination of fusion regulatory frameworks. The U.S. is emphasizing international partnerships as part of a broader reorientation of its fusion program around the goal of deploying a pilot fusion power plant in the 2030s.

FYI is a trusted source of science policy news, published by the American Institute of Physics since 1989.

Using Physics to Design the Stages of Broadway and Cirque du Soleil

Bart Breisch relies on his physics background to create safe sets for extraordinary performances.

BY ALAINA G. LEVINE

If you've ever been to a Cirque du Soleil show, you probably remember gravity-defying acrobatics and feats of raw human talent. But behind the scenes of every stage-worthy performance, careful engineers are working their own magic.

Behind every stage-worthy performance, engineers are hard at work.

Bart Breisch is one of them. A physics major turned structural engineer, Breisch works in the entertainment division of a New Jersey-based firm called McLaren Engineering Group, designing and installing massive structures for a variety of performance sets.

"The fields we work in are fairly diverse, and that makes it a lot more interesting," he says.

Breisch has helped create structures for Broadway productions, like custom stages, overhead architectural pieces, and the building renovations needed to accommodate them. He's worked on projects for live events like high-profile concert tours, fashion shows, Disney and Universal theme park attractions, and Cirque du Soleil shows.

Once Breisch and his colleagues understand a client's vision, they can bring it to life with engineering, physics, and art, while reducing risks for everyone involved. "Our work is very focused on life safety," he says, "whether it is acrobatics, or people walking around on something, or it's something hung over head." Projects can require anything from stage and set architecture to moving equipment, including huge winches, rigging, and beams that support cast, crew, and scenery.

Bart Breisch

With a bachelor's degree in physics and a master's degree in structural engineering, Breisch's education helps him navigate the complexity of set production without losing sight of the big picture — the wow factor each project aims to achieve.

"A physics degree gives you the tools to think independently and creatively about the world around you," he says. "That can be applied to almost anything."

Breisch recalls a recent project for the Houston rodeo, an event that draws millions of people annually. The team was tasked with designing and creating a bespoke, moving, star-shaped stage. Each arm of the star pointed upwards, with performers positioned on each tip while the star spun. "All of the weird motions and movements required very custom calculations," he says. "Whether it is performer flying or mechanized effects, [any time] you have motion, I go to the basic kinematic equations."

And not all designs are as simple as they seem. For example, a performance pole is a common stage element for Cirque du Soleil, used by dancers and acrobats to hoist and twirl themselves. "[But] there's a lot more very custom math that goes into it that isn't in the building code," he says. "When you get into these custom acts, you need to be able to accurately quantify and understand what forces are being applied to your structure. This is Physics 101."

For one Cirque du Soleil production, Breisch helped design a series of motorcycle ramps. The team had to calculate how much force would be applied in every location, and how the ramps would be used, based on the planned performance and the requirements of the performers, crew, and audience. What happens when the bikes land? How do different bike models change the impact load? How does tire pressure affect the bikes' movement, speed, and safety on the ramps?

"I spent a lot of time digging into how motorcycles work — the kinematic equations, acceleration," he says. "It takes a lot of time, creativity, and effort to think about all the variables that go into just a rider going up and coming down on a motorcycle." Every question was colored by Breisch's physics training, and the performance was a hit.

Breisch has been with McLaren for 10 years, and he still gets a kick out of his work. "I was looking to do something interesting, and I didn't want to go the route of going to a structural engineering firm and only designing parking lots the rest of my life," he says. "Seeing new puzzles every day helps keep me going."

Alaina G. Levine is a professional speaker, STEM career coach, and author of the books Networking for Nerds *(Wiley) and* Create Your Unicorn Career *(forthcoming).*

March Meeting continued from page 2

national members at synchronous events around the world. Meetings will be held, at a minimum, in Jordan, Pakistan, Brazil, Hong Kong, and Nepal.

Virtual March Meeting: Chaikin also points out that this year's virtual March Meeting has been reimagined, thanks to feedback from APS members. One major change: The virtual meeting will run at the same time as the in-person event. Live presentations and virtual poster sessions will allow for real-time interaction, with in-person and virtual recorded presentations available for all attendees for 90 days after the meeting.

Whether you're a biophysicist, cosmologist, or quantum physicist, if you're planning to participate in March Meeting 2024, Chaikin extends a "warm" welcome — and a reminder to bring a winter coat if you'll be joining in Minneapolis!

Learn more about the March Meeting at march.aps.org.

Liz Boatman is a science writer based in Minnesota.

Green Bank continued from page 1

GBO is somewhat protected by the National Radio Quiet Zone, a 13,000-square mile area surrounding GBO and U.S. facilities in Sugar Grove, West Virginia, where radio emissions are federally regulated (although satellite and airplane emissions are exempt). Stricter restrictions stem from the West Virginia Radio Astronomy Zoning Act, which allows GBO to prohibit electrical equipment that interferes with observations on its campus and within a ten-mile radius.

The observatory's juxtapositions go beyond its scientific requirements. The small town has an unusually high percentage of people with Ph.D.s, but K-12 students have limited academic opportunities, and aside from the observatory, there aren't many places to work.

GBO's campus, with the Green Bank Telescope in the background. Credit: Jay Young/GBO

"Ninety percent of the people who are qualified to work at the observatory would probably not be interested in living in such a rural location," acknowledges Lockman. Still, he doesn't feel isolated. GBO hosts thousands of visitors annually from the local area and scientific community. "We have people coming through all the time," he says. "It's possible to really feel connected to the scientific community."

GBO software engineer Victoria "Cat" Catlett, who uses the pronoun they, agrees. After earning a physics bachelor's degree in 2022 from the University of Texas at Dallas, they took a job at GBO sight unseen — a snowstorm thwarted the in-person interview. It felt like a big risk.

"I was worried about being disconnected from everybody," Catlett says. "[And] since the town is so small, my co-workers would have to be my friends." But they've found the people friendly and passionate, the science fascinating, and the unique culture a good fit. And as for the Wi-Fi restrictions? "It's actually been a little freeing to be able to completely disconnect."

Kendra Redmond is a writer based in Minnesota.

Nobel Lectures continued from page 1

tremely small, the scale of attosecond physics is dizzying: There are as many attoseconds in one second as there are seconds in the 13.8 billion years since the Big Bang. But electrons move at a blistering 43 miles per second, so flashes of light on the order of attoseconds are the only ones brief enough to provide a snapshot of an electron's motion.

It was the pioneering work of Anne L'Huillier (Lund University), Pierre Agostini (Ohio State University), and Ferenc Krausz (Max Planck Institute/Ludwig-Maximilian University) that opened the world of electrons for all to see. On Dec. 8, in a packed auditorium at Stockholm University, each took the stage to tell their story.

L'Huillier — only the fifth female laureate in the history of the physics Nobel Prize — laid the groundwork for the field by studying the light emitted from shining lasers through noble gases. In the late 1980s, L'Huillier discovered that when an infrared laser was shone through ionized argon, the resulting light waves had increasingly high frequencies, a phenomenon called harmonic generation. "It's similar to what happens when the bow of a violin hits the string," L'Huillier said in her lecture. "It produces not only the intended note, but also overtones."

L'Huillier theorized that if two harmonic waves were aligned just right, they could interact in a way that generated extremely short flashes of light. "Think of a gigantic orchestra where all the musicians need to keep the same pace," she explained. "Except each musician in this orchestra is an atom, and there are trillions involved."

As laser technology advanced, physicists raced to make attosecond pulses a reality. In 2001, Agostini did just that. His team was able to generate a train of consecutive ultra-fast light pulses thanks to an ingenious setup in which a laser light was divided into two beams, refracted through a series of glass windows, and then brought together again, ensuring correct synchronization of the harmonic waves. Agostini was also able to measure the pulses, which clocked in at an astonishing 250 attoseconds.

"Children everywhere deserve the chance to realize their dreams," Krausz said to applause. "We badly need all of them to carry on once our own time comes to an end."

With characteristic humility, Agostini emphasized how much these methods have improved. "This was 20 years ago," he said. "The pulses have now shrunk to 43 attoseconds, and soon we'll have the zeptosecond" (10^{-21}).

But the progress can't continue forever, according to quantum mechanics. "It takes more and more energy to produce shorter and shorter pulses, and eventually we will hit Planck time (10^{-44} seconds) — that's the absolute limit," he added.

With the technology to create attosecond pulses in hand, physicists sought to use them to snapshot electrons in motion. In 2010, Krausz's team used attosecond spectroscopy to capture high-speed phenomena, including the photoelectric effect (in which light rips electrons from an atom) and the oscillations of a cloud of electrons around a nucleus. "Attosecond spectroscopy furnishes us with a temporal magnifying power that is equivalent to the combined magnifying power of a space telescope and an electron microscope," Krausz said.

In his lecture, Krausz highlighted the application of attosecond spectroscopy to biological materials as one of the most impactful future uses of the technology. His team has already embarked on this: By identifying "electric field molecular fingerprints" associated with cancer, Krausz's team has been able to distinguish between blood samples of early-stage lung cancer patients from healthy controls with >90% accuracy — an encouraging sign that this technology may one day be harnessed for disease detection.

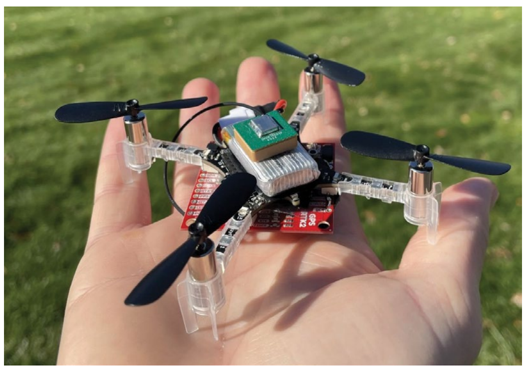
The science behind this year's Nobel Prize is impressive, but one of the most moving aspects of the event was each laureate's humility. All three gave heartfelt acknowledgements to their mentors, colleagues, and former students, many of whom sat in the front row of the audience.

Krausz also highlighted another champion of physics — the next generation of scientists. "Children everywhere deserve the chance to realize their dreams," he said to applause. "We badly need all of them to carry on once our own time comes to an end." He will donate his share of the 11 million SEK in prize money (~$1,080,000) to support education programs for children whose schooling has been disrupted by the war in Ukraine.

Abigail Dove is a writer based in Stockholm, Sweden.

Drones continued from page 1

shape, and concentration. These properties influence the amount of time a particle stays adrift or its likelihood of undergoing certain chemical reactions, Hong says. This data can inform large-scale climate and atmospheric models.



LaDrone consists of a GNSS antenna, receiver, and datalogger built on a Crazyflie drone. Credit: Nate Simon

It's challenging to track smoke because it moves on the scale of kilometers, but researchers also need to make measurements on the scale of the individual particle, which are microns in size. "You need to understand how the small particles change in composition as they move in the atmosphere, and at the same time, you need to track those particles," says Hong.

Simon's team opted for a more minimalist approach. Other than producing a force to counteract gravity, their drone "just passively goes wherever the wind takes it," he says. The aim is to have the drone drift with the wind and track the motion of individual atmospheric particles. Simon presented this drone as an alternative to balloons used to track wind. Engineers have tended to make balloons bigger in order to outfit them with necessary instruments, but the size prevents them from tracking individual particles.

While the drone drifts with the wind, it still has the movement capabilities of a conventional drone. Researchers can operate the drone in passive or active mode to study different atmospheric phenomena. "Maybe being completely passive is not the most efficient way to gain as much information as possible about the flow," says Simon. "Maybe you want to kind of jump between particle streamlines."

One challenge was building the system that tracks the drone's location to within a centimeter, which is necessary for atmospheric science studies. Conventional GPS technology could only pinpoint its location to about 2.5 meters, says Simon. But he applied a data processing trick to improve the GPS's precision. By collecting location data from the drone and a stationary laptop on the ground, he could reduce the drone's position error.

Simon's team plans to continue testing the drone in real-world conditions. They also want to improve the drone's design. In its current form, the drone is sensitive to weight changes. "If you added a gram or two, it wouldn't take off," he says. So instead of using off-the-shelf components, they want to construct parts of the drone, like its printed circuit board, to be more weight-efficient.

Hong, meanwhile, plans to fly the drones through a prescribed burn at Cedar Creek in Minnesota, where controlled burns have been conducted since the 1960s. He also wants to explore the best way to coordinate as many as eight drones in his fleet. Currently, they follow a hierarchical command, where one drone overseeing the scene controls the others. Researchers are still investigating how to optimize drone coordination, he says. The research ultimately aims to track particles over kilometers, measurements that could inform environmental researchers or public health departments.

Sophia Chen is a writer based in Columbus, Ohio.

APS, Partners Help Members Navigate Anti-DEI Laws

BY TAWANDA W. JOHNSON AND JULIE DAVIS

In the last two years, dozens of state governments have proposed legislation to limit or ban diversity, equity, and inclusion (DEI) programs and policies in public colleges, universities, and other institutions. Many in physics have expressed alarm, concerned these bills could harm research, teaching, and diversity in the field.

Florida passed some of the first laws targeting DEI initiatives in public colleges and universities. Credit: Katherine Welles - stock.adobe.com

"Most people are not sure what to do," said Katheryn Russell-Brown, a law professor at the University of Florida, located in a state that has passed some of the first and most extreme anti-DEI laws.

To help members navigate these changes, APS, the American Association of Physics Teachers, and the National Society of Black Physicists sponsored two webinars on the topic — one on laws in Florida, led by Russell-Brown, and one on national legislation, led by Jeremy C. Young, program director of Freedom to Learn at PEN America, the professional society for writers.

One of the big takeaways: Most DEI work can continue.

"Can you achieve the same programmatic goals you had before the passage of SB 266?" asked Russell-Brown, referring to a Florida anti-DEI law that took effect in July. "I would say that the answer is yes, but it will require some different strategies."

Colleges in Florida are far from alone in grappling with these laws. Since January 2021, there have been 99 proposed anti-DEI bills in 33 states, 12 of which have passed in nine states, said Young. These bills could shape higher education curricula, teacher training, and beyond.

Young noted that many of these laws are often vague and difficult to administer — by design. "The vagueness is the point," he said. The laws are rarely enforced; rather, they're "designed to cause you to self-enforce, rather than to follow the direction of the law."

Both experts offered advice on how members can work with their institutions and advocate for change.

Russell-Brown recommended that educators present program ideas in writing to department leadership, to ensure "that your intentions aren't misunderstood" and that programs comply with SB 266. She also suggested that educators use existing programs at their institutions as models, and keep colleagues informed of their plans.

Young advised educators to avoid over-compliance. "Don't do the censors' work for them," he said. "Wait for someone to actually tell you something is banned before you act as though it's banned." Members of the public can also help by speaking up, if possible, Young said — by writing op-eds and letters to the editor, for example, and talking with family and friends about the laws.

And importantly, Young says, don't go it alone. "These laws affect all elements of higher education institutions pretty much equally," he said. "There is an opportunity here for unprecedented unity and coalition-building."

Watch the webinar recordings at aps.org/webinars.

Tawanda W. Johnson is the APS Senior Public Relations Manager at APS. Julie Davis is an APS Federal Relations Senior Associate.

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That's the support Sebastien Lepine, physics chair at Georgia State University in Atlanta, a predominantly Black institution, was looking for when he reached out to EP3.

"Our goal is to be one of the leading institutions for graduating students from African American and Hispanic populations with physics bachelor's degrees," says Lepine. "We have a large undergraduate program ... [but] we're right next door to Georgia Tech, which has a very prestigious engineering program. So a lot of students might come here first to get their grades up, then try to transfer."

Lepine says his department, which has about 250 undergraduate physics majors, was also looking for opportunities "to strengthen the connection between the major in physics and the associated career opportunities," to increase retention of those would-be transfer students.

Lepine says retention issues have grown because of changing student demographics. These days, many physics majors at Georgia State commute, and have a job on the side to support their families, he says. "We need to be adaptive and give them a way to complete their degree," while honoring those constraints, says Lepine.

The department was also seeking creative ways to help physics students finish their degrees. Lepine says his faculty knew that research experiences could be extremely motivating, giving undergrads the chance to apply what they're learning. But the faculty weren't rewarded for working with undergrads, in terms of promotion and tenure, and the salaries the department could offer for summer internships couldn't compete with private-sector jobs.

Georgia State's physics program had already undertaken some dramatic changes, says Lepine, but "a lot of the activities that we're trying to do will at some point require more resources" from the university, like scholarships and better summer salaries for interns.

So when Lepine learned about the EP3 site visit program, he jumped on it. "This is exactly what we need — validation from somebody from the outside" that his department's efforts were on the right track, he says.

The site visit motivated his faculty and helped his department craft an action plan, he says. "The questions the committee was asking created a lot of discussion inside the department and helped us brainstorm ideas."

Lepine says his department has already implemented five action plan items — "but we have a long list to go."

Liz Boatman is a writer based in Minnesota.

BACK PAGE

To Do Better Science, Try Dance

How growth in the arts made me a stronger science communicator and engineer.

BY NICOLE XU

I won't sugarcoat it: My first scientific presentation was a disaster.

It was January 2016, and before I even walked onstage, my stomach had twisted into knots. Sweat beaded on my forehead, and the more I tried to will it away, the more it dripped down my face.

"Let's bring on the next speaker," the session chair announced, and my lead feet carried me up the stairs to the stage. I squinted into the audience to see familiar faces, but the only thing I could see past the spotlights were cold silhouettes. As I spoke, I fidgeted in and out of the microphone's range, knowing how bad it sounded but unable to stop, as though a novice puppeteer were pulling my strings. I stuttered and stumbled — all those meticulous notes, lost in translation.

After the longest 15 minutes of my life, I slunk back to my seat, pleading silently with the universe to never, ever make me speak publicly again. Wishful thinking, of course. That's not how research works, or life. I'd have to give more talks. I'd have to present to more strangers.

On my way home, I thought about the calm, collected communicators I admired most. How could I make the leap from nervous wreck to skilled presenter? What was the secret scientific ingredient I was missing?

Ironically, it took something seemingly *un*scientific — dance — to help me find the answer.

When I was growing up, science and the arts seemed diametrically opposed: Black-and-white objectivity on one side, squishy subjectivity on the other. The "typical scientist" trope fit the dichotomy well: There he was (always a he!), the lone genius toiling in his lab, too busy for frivolous arts.

Try as I might, I didn't fit the trope: I liked the arts, particularly dance. After an inspiring dance fitness class in college, I kept up the passion, attending classes and dreaming quietly of teaching them. "I never would have guessed you're an engineer," well-meaning people, seeing me in my workout gear, would say, oblivious to the sting.

For years, I kept my two worlds separate. I would choreograph songs in my head while walking home from the lab, and that's about it. Who had hobbies in grad school anyway? Between research and coursework (and routine existential dread), I barely had time to sleep.

This changed in December 2016. One day after my dance class, I offhandedly asked my instructor how she started teaching dance. Her face lit up, and before I knew it, she had talked me into one-on-one training sessions and an expedited audition one month away.

After a few lessons, I performed a practice audition. It went about as well as my first conference presentation did, with the same stomach knots and shaking hands. I botched the choreography countless times.

But it also felt different from my first presentation. *Well duh, I wasn't perfect in my practice audition*, I thought — *I've never done it before!* It felt easier to shrug off my errors and incorporate my instructor's constructive feedback, and I dove into practice.

The day of my real audition class finally rolled around. I had sheepishly invited friends and colleagues to attend, including my Ph.D. advisor and lab mates. They all came, and I looked out onto a sea of strangers and familiar faces alike. My heart thumped with worry, but the music thumped louder, and I tried to reflect the audience's energy back tenfold. I still made mistakes, but I shrugged them off, finishing strong and riding the adrenaline rush home.

Before I had even unlocked my door, an email from my dance instructor lit up my phone screen. "YOU'RE HIRED!" it read. The instructors had agreed unanimously to bring me onboard, no discussion needed. "I hope you find time for teaching, no matter what you do in your career," she added.

I thought through the process. Screwing up in a dance audition had felt normal and forgivable — but screwing up during a conference presentation had felt like a mortal sin. Why had I judged myself so harshly for my presentation mistakes? Hadn't both efforts gone equally terribly? And just as my practice audition had been a nightmare, practice presentations in the lab were torturous: I dragged myself into each conference room like I was walking up to the guillotine.

The disparity made no sense, and it dawned on me how much havoc the "lone genius" trope in science had wreaked in my mind. It left no room for errors or awkward laughter — no room for the messy fun of the learning process, including practice. The stakes felt high with my presentation because I had assumed a good scientist doesn't make the kinds of mistakes that I did.

The more I taught my own dance classes, the more comfortable I felt with public speaking and presenting. Science and the arts, it turns out, have more in common than I had originally thought.

In fact, my background in science helped me structure a cardio dance class. How do I design a total-body workout in 16 songs? What's the right formula for a routine that includes cardio, strength training, a warm-up and cool-down, and stretching, all without overexertion? What challenges, such as injuries, should I adapt to? So much in dance requires the methodical, logical planning I use every day in physics.

And I realized just how many lessons from my artistic life applied to my scientific life. A conference presentation *is* a performance — an exercise in speaking clearly, engaging individual audience members, energizing a crowd, and teaching effectively.

With a new mindset and a renewed commitment to the learning process, my presentations improved over time. And now, as a professor, I stress to my students that it's okay to slip up, even under stakes that seem high — in front of important professors, or in front of an entire conference audience. The key is recovering in real time, which, as a dance instructor, I do in nearly every class. I've tripped. I've forgotten choreography. Once I swallowed a bug (but hey, so did Taylor Swift!). Seasoned professionals become seasoned by screwing up. Instead of criticizing myself, I've worked to find humor in my mistakes. It's much easier to teach a dance move or give a talk when I'm having fun, and it's much easier to improve when I don't beat myself up for being human.

This lesson feels especially important for young women in physics, who often face pressure to bend to the norm of the (often male) "ideal" scientist. There is no such ideal, of course. It's a myth, and it does damage.

Instead, if you'd like to do better science, try singing, dancing, or improv. Leap into a creative, artistic endeavor that takes you outside your comfort zone and lets you practice the art of learning, failing, and growing. Find a community outside of work that invigorates you.

And for the overachievers skeptical of devoting free time to 'non-productive' activities — a topic for another day — don't forget that these creative efforts aren't just fun. They'll make you a stronger scientist, too.

So, won't you try a dance class?

Nicole Xu is an assistant professor in mechanical engineering at the University of Colorado Boulder. An expanded version of this article will appear in Stories of Women in Fluids: Persevere, Survive, and Thrive, *an anthology, supported by the APS Division of Fluid Dynamics, intended to inspire women early in their fluid dynamics careers.*

STEP UP continued from page 3

In her cohort, "teachers have been sharing stories from their students that we are making a change, we are getting students to think critically about how they perceive physics and science in general," Bowns-Kamphuis says. That impact is right on target, she adds, and could inspire more students to report their intention to pursue physics in college, a key program metric.

Poluan, Bowns-Kamphuis, and Levy are also enjoying the experience of bringing so many physics teachers together.

"My team is focusing on the relationships between all the physics teachers in our region — building that sense of community," says Poluan. In the Los Angeles area, about 20 teachers were trained in last year's cohort and are working on implementing the program's lessons in their classrooms.

Soon, the coordinator's efforts will shift more toward recruiting the next cohort. "I'm really hoping that the teachers who are a part of our current cohort had a good experience," Bowns-Kamphuis says, "because we'd like to get more teachers from those schools, perhaps even entire departments."

STEP UP's current effort is bolstered by partnerships with local PhysTEC institutions — a network, supported by APS and AAPT, of colleges and universities that train

> "Physics is a human subject — humans are doing it," she says. "STEP UP has helped show this, and we really needed that in physics."

physics teachers. These partnerships are invaluable because PhysTEC programs train many educators who go on to teach high school physics.

For example, says Levy, a connection with Stony Brook University in New York has created a natural opportunity to get STEP UP materials into the hands of teachers in training, so they're prepared to teach the lessons before they've ever set foot in a classroom of their own.

STEP UP just received another grant from the National Science Foundation's Discovery Research PreK-12 program. "We'll use this one to focus on building professional development activities for teachers, specifically around the 'Everyday Actions Guide,'" says Barnett Dreyfuss. The guide, created by STEP UP, outlines steps any teacher can take daily or weekly to support students from historically underrepresented groups in physics.

The new grant will also help the STEP UP team develop specific, tailored materials to support teachers facing unique challenges, like resistance in the community to topics around diversity, equity, and inclusion.

Most importantly, Poluan thinks STEP UP has helped humanize physics, which is crucial for inviting women and students from other underrepresented groups into the field.

"Physics is a human subject — humans are doing it," she says. "STEP UP has helped show this, and we really needed that in physics."

Are you an educator interested in STEP UP? Visit engage.aps.org/stepup.

Liz Boatman is a science writer based in Minnesota.