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Theoretical Physicist Awarded Valley Prize for Work on Quantum Gravity

Geoffrey Penington's groundbreaking work as a graduate student has helped kickstart advancements in quantum information.

BY KENDRA REDMOND

Geoff Penington *Credit: Lee Sandberg / Institute for Advanced Study*

Geoffrey Penington first encountered theoretical physics as a kid, through the pages of Brian Greene's *The Elegant Universe*. Captivated by the questions it explored, Penington remembers thinking how cool it would be to work on those subjects. But he never thought he would.

"I always thought I'd end up doing something else, but it was nice to imagine," he says.

Now, in recognition of his groundbreaking work on quantum gravity, APS has awarded Penington the 2024 APS George E. Valley, Jr. Prize. The prize is given annually to an early-career individual who has made an outstanding scientific contribution deemed likely to have a dramatic impact on the field.

Although Penington didn't think he'd become a theoretical physicist, he decided to follow his interest as long as it was fun and he had a job. That led him to Patrick Hayden's quantum information science group at Stanford University. While a graduate student there, Penington distinguished himself by applying new insight to the infamous black hole information paradox.

In the 1970s, Stephen Hawking applied quantum mechanics to black holes and realized that an isolated black hole will radiate energy and then evaporate, says Penington. While that's not unexpected, "the really weird thing about Hawking's calculation is that it seems to suggest that the radiation that escapes has nothing to do with the mass

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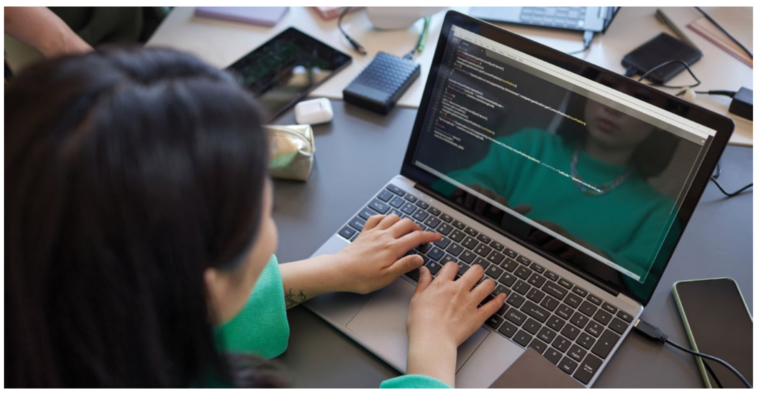
How to Strengthen Computing Instruction in the Physics Classroom

Better computational training is needed to prepare physics students for the workforce, says researcher Danny Caballero.

BY RACHEL CROWELL



Modern physics research and computing are so deeply intertwined that many students' future careers will depend on strong computational skills — from knowing programming languages and developing data visualizations, to creating computational mathematical models and "mining [datasets] for patterns and structure," says Danny Caballero, a physics education researcher at Michigan State University.

Those skills need to be deep and broad enough to serve students regardless of whether they plan to work in academia, at government laboratories, or in private industry. "One of our recent graduates is modeling WiFi attenuation for a company," Caballero says. "Another is employed by a cereal company, drawing meaning from their vast sales data."

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Once a Crystal Collector, Now a Crystal Scientist

Since earning his doctorate in solid-state physics through the APS Bridge Program, Brian Casas says it feels like life has come full circle.

BY LIZ BOATMAN

Brian Casas has liked crystalline solid-state materials his entire life — long before he knew that's what they were called. As a kid, he decorated his parents' house with rocks he found, eventually becoming an avid crystal collector.

"That's why I started college as a chemistry major, thinking that was how I could understand materials and their properties," he says. "But I ended up moving into physics because ultimately I wanted to understand the complex states of matter that exist within crystalline materials."

Today, Casas, an APS Bridge Program graduate, is a senior process engineer in crystal growth at Coherent Corp., a Pennsylvania-based company that engineers materials for diverse applications. The program, established in 2012 to increase the number of underrepresented minority students who earn PhDs in physics, now has 47 partner schools across the country. Partner schools — which retain more of these students than the national average — have graduated 27 students since 2019, doubling what the data projects the graduation rate would have been without the Bridge Program.

Brian Casas

At Coherent, Casas puts his skills to work as a crystal grower. "It's in-

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Restructuring Classes Can Level the Playing Field

A study of university-level physics classes shows that changes in course structure can help eliminate grade gaps between student groups with different races, ethnicities, or genders.

BY KATHERINE WRIGHT

When it comes to addressing diversity in physics, a common refrain from those against change is that inclusion lowers standards. Believers of this dictum think that efforts aimed at increasing the number of underrepresented students studying physics—and keeping them in the field—requires putting in place accommodations that will diminish excellence in the field. Results from a new study that looks at sources of demographic grade gaps in undergraduate classes show the opposite: leveling the playing field does not require lowering standards. The study finds that relatively simple adjustments to the structure of a course—not its content—can remove grade gaps between white male students and those from marginalized groups. The researchers behind the study hope that the findings will motivate educators and institutions to reflect on their teaching methods and implement changes that will make the physics classroom more equitable.

"Making small changes to a course's structure can eliminate equity gaps in course grades," says Cassandra Paul, a physics education researcher at San José State University, California, and one of the people behind the new study. "It's not the students that need fixing, it's how we serve them."

Credit: Antonio Rodriguez / Adobe

The study conducted by Paul, together with David Webb of the University of California, Davis, considered two course-format alterations. One switched up how the students were taught, the other how they were assessed. The teaching-method change, which the duo terms "concepts first," involved rearranging the order in which the teacher presented the elements to be learned. Traditionally, university lecturers take a topic-by-topic approach, which drip feeds the concepts to students while simultaneously starting them on complex calculations. The concepts-first method, by contrast, splits these two elements apart. In the first 60% of the semester the teacher familiarizes the students with the concepts they need to understand, drilling down into the details of each one. The semester then finishes up with the students using that knowledge to solve problems on a variety of topics.

The assessment change allowed students to retake exams without penalty. In the unaltered version of this class, the students were continuously quizzed on what they were learning in weekly 20-minute tests, with a final exam at the end of the semester. In the retake version, the weekly tests were swapped with fortnightly ones. That left an intervening week between tests, where students were given the option to retake the previous week's test. The retake test covered the same material, and, if higher, the retake grade supplanted the original score. Retaking was optional and was only allowed for the fortnightly tests and not the final exam.

The concepts-first idea was implemented by Webb in an introductory calculus-based physics class designed for physics and engineering majors. In the same semester, he taught the class to two separate groups of students, with one group following a concepts-first format and the other topic by topic. "Ev-

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Science From a Bike: One Teacher's Cycling Journey to Share Physics Experiments Around the World

Michael Gregory leans on APS JNIPER's coffee hours and workshops to support his global outreach efforts.

BY LIZ BOATMAN

A Canadian man named Michael Gregory has bicycled the equivalent of a lap around the Earth, through some 40 countries, for one purpose: sharing physics with teachers and students.

"It helped that arriving by bicycle was a point of interest," he says.

Gregory, who has taught science in four countries, says he's seen firsthand how an idea can start in one classroom and "spread first throughout a school, then a district, region or country" — but translating across borders or languages tends to be slow.

Six years ago, to share ideas for educational experiments, Gregory launched "My Favourite Experiments," a YouTube series showcasing K-12 physics experiments for teachers. But to build the project's collection, he needed to connect with many more science educators.

So he bought a bike, negotiated a reduced contract for his teaching job in San Francisco, and hit the road, first pedaling north to his home country. There, he began 'cold connecting' with science teachers across Canada. The effort he put into cycling to meet teachers and students demonstrated his commitment to the project, he says.

Then, in fall 2022, APS launched the Joint Network for Informal Physics Education and Research (JNIPER). The community is tailored to folks like Gregory, who design, facilitate, or study informal physics learning activities. Registration for JNIPER activities is free, and APS membership is not required.

Gregory has been a regular attendee of JNIPER's virtual monthly "Coffee Hours," each of which features a different guest speaker. The coffee hours — all recorded and freely accessible on JNIPER's YouTube channel — have offered "a great opportunity to meet like-minded people who are dedicated to high-quality physics education," he says.

Today, Gregory is France's Ambassador for Europe's two biggest science teaching networks, Science on Stage and Scientix. For Science on Stage, Gregory organizes a monthly online meeting, "Experiment Share," which features live science experiments presented by teachers in 5 to 10 countries.

Another series is "Science on Your Stage," in which Gregory aims to run workshops in every country he visits. On his most recent adventure, Gregory cycled across the Sahara Desert from Morocco to Senegal, stopping along the way to give free science shows featuring low-cost experiments.

Gregory's "My Favourite Experiments" YouTube channel now boasts more than 200 videos of experiment demonstrations, most 10 minutes or less. Some have received thousands of views, and hundreds of teachers and students have participated. The content is free for everyone.

But producing outreach content is only half the battle. Gregory says he's realized the importance of evaluation, to ensure that his efforts are actually helping science teachers. JNIPER's workshops have given him tools to use for evaluation, and they've boosted his confidence as he plans and implements those assessments.

For example, he's used the assessment tools in his new project, a course called "Particle Physics for Teachers," and his new science show, "Particle Detectives," developed in collaboration with CERN. In its first two weeks, Gregory has performed "Particle Detectives" in Kazakhstan, Italy, and Serbia, and it's been translated into five other languages.

Gregory presented both projects at JNIPER's September Coffee Hour and was thrilled by other attend-

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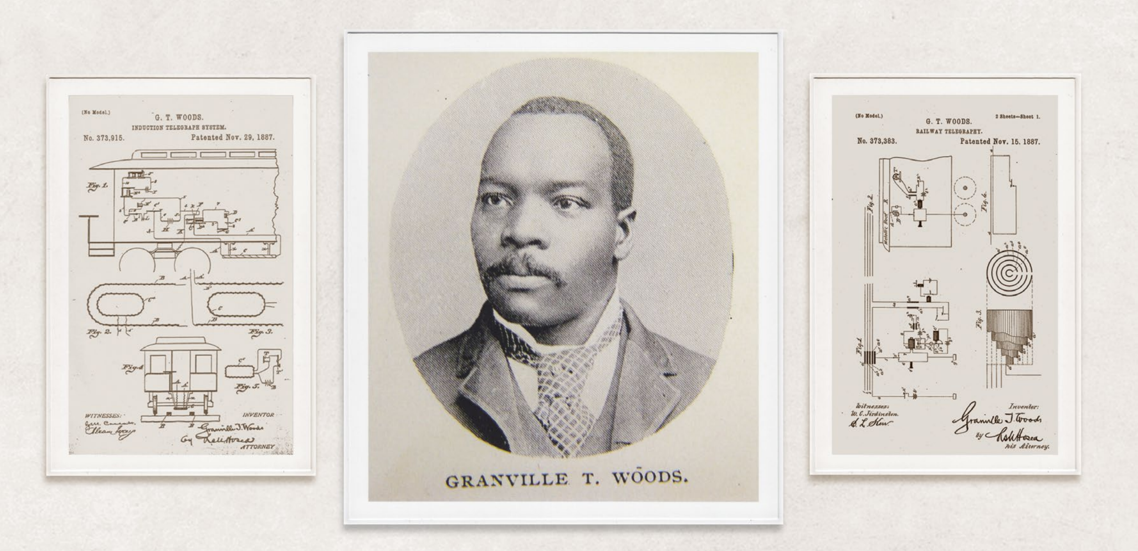
Michael Gregory demonstrating Bernoulli's principle outside of a school in Machraa Ben Abbou, Morocco. *Credit: Michael Gregory*

THIS MONTH IN PHYSICS HISTORY

November 1887: Granville Woods Patents the Induction Telegraph

The invention, which allowed stations to communicate with trains and prevent collisions, soon locked Woods in a patent battle — one of many in the prolific inventor's life.

BY TESS JOOSSE



A portrait of Granville T. Woods. *Credit: Portrait from* The Cosmopolitan Magazine *in 1895; patents from US Patent Office, patents 373,915 and 373,383.*

In February 1885, Granville T. Woods came across a troubling article in *Scientific American*. According to the story, an inventor named Lucius J. Phelps created a system for sending a telegraph message to a moving train. While this was good news for railway safety ("the risks of disaster on railways will, by this means, be greatly reduced from this time onward," the story proclaimed), it was bad news for Woods. Four years earlier, he had designed a nearly identical invention, an "induction telegraph," but had contracted a nasty bout of smallpox before he could patent or publicize it.

> "There had been no research done on Woods since 1887," the historian M.A. Harris said. "Yet this man had performed such magic."

Soon Woods — then nicknamed the "Black Edison" for his inventive contributions — was locked in a patent investigation battle over the induction telegraph. It was just one in a long line of struggles Woods experienced trying to profit from his inventions. "He spent the majority of his adult life marginalized as an inventor, desperately struggling to secure funding and gain a respectable reputation for his work," writes Rayvon Fouché in *Black Inventors in the Age of Segregation: Granville T. Woods, Lewis H. Latimer, and Shelby J. Davidson.*

Woods was born on April 23, 1856. Where, exactly, is a bit of a mystery. Many biographies say Ohio, but Woods himself claimed he was born in Australia, probably a lie he told "to garner respect and dissociate himself from slavery in the United States," according to his obituary published in 2019 in *The New York Times*.

Other facts about Woods' early life are similarly cloudy. He possibly received some technical schooling and worked for an iron company, as a firefighter, and aboard a British steamer ship. In the 1870s, he found employment as an engineer on the Dayton and Southeastern Railroad in Ohio, where it's likely some of his later train- and electricity-focused inventions took root.

In later patent-interference case testimony, Woods described how a telegraph operator in a town along the rail route showed him how to use the machine. Invented in the 1830s and, by 1880, the gold standard for long-distance communication, the electrical telegraph worked by pressing a button to form electrical circuits and pass signals over wires, to be received by a telegraph sounder in a pattern of Morse code dashes and dots that could be translated into a message.

On another visit to the town in late 1880, Woods rode an elevator in the local hotel and invented a method for improving the elevator's signaling between floors with induction. The idea was to attach one wire, wound around a metal core, from the bottom floor to the elevator. This wire would pass through another wire that was wound around a spool and connected to each floor of the building. A passenger on one floor could push a button and complete a circuit with the first wire, while an impulse inductively moved to the second wire, alerting the elevator operator to send the car on up.

Woods ended up abandoning the idea, and he quit his job on the Ohio railroad. But he kept inventing, and soon settled in Cincinnati without a steady job. "Woods's day-to-day activities can best be described as surviving and even hustling," writes Fouché. Woods saw inventing as his best way to make money.

Woods' early experiences working on the railroad likely taught him the danger posed by two trains on a collision course. Stations couldn't reliably communicate with moving trains, and early visual signaling systems were imperfect and prone to error. "The public prints give us almost daily accounts of railway collisions in one section of the country or another," read the 1885 article in *Scientific American*.

In early 1881, Woods designed a railway communication system using existing telegraph lines, which ran along or near many train routes. One wire, connected to a train station's telegraph transmitter-receiver, would be routed above the tracks on poles or connected to a wire embedded along the tracks with an inductor. Another wire and inductor would be carried by the train car itself, accompanied by a transmitter and other apparatuses for receiving a telegraph message. As the train chugs along, its inductor passes over the inductor embedded in the tracks, creating mutual inductance through which electrical signals can be passed.

Before Woods could test the creation or file a patent, he fell ill with smallpox in August of 1881. For months, Woods languished in bed, and even after he recovered, his health was never the same.

After his recuperation, he built several models of the induction telegraph and refined its design. By the time he read of Phelps' work

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Start Your Search For a Summer REU Now (and Other Advice From a Physics Major)

Anne Monroe, a college junior majoring in physics, reflects on her internship experience and shares advice.

BY LIZ BOATMAN

Barely back on campus for her junior year at Gustavus Adolphus College in Minnesota after a summer research internship in Montana, physics major Anne Monroe is already thinking about what type of internship she'll do next summer.

"I've always wanted to be a part of science as a whole, to be part of a team working to add to the collective body of human knowledge," says Monroe.

Her internship, part of the federally funded Research Experiences for Undergraduates (REU) program, gave Monroe the chance to work directly with research scientist Aki Takeda in Montana State University-Bozeman's Solar and Space Physics Program. Under Takeda's mentorship, Monroe sought to help answer an important question: Does the Sun's x-ray irradiance — a measure of the amount of light that reaches Earth — vary with latitude?

Anne Monroe in Montana during her summer research internship at MSU-Bozeman. Credit: Lane Scheel

It's an interesting question, says Monroe, in part because the Sun, a ball of plasma, experiences what's known as "differential rotation," where the plasma near the poles takes much longer to complete one revolution than the plasma at its equator. In contrast, all of Earth completes one revolution in just 24 hours.

Monroe says gaining insight into the Sun's x-ray irradiance could increase our understanding of sunspots, associated with solar flares and coronal mass ejections. These ejections emit plasma, x-rays, and

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teresting — I'm in the production group," he says. "This means I'm looking at the quality of crystals weekly, trying to identify emerging problems or concerns or deviations from what we expect, and then working backwards to find the root cause and correct it."

Despite working in physics today, Casas didn't take his first physics course, AP Physics, until his senior year of high school, in 2008. "It demolished me," he says, even though he'd been a star chemistry student in his school's accelerated science track since middle school.

> Compared to chemistry, physics was "an entirely different mode of thought," Casas says. "Suddenly there was open-ended problem solving and a mantra of 'derive, don't memorize.'"

Compared to chemistry, physics was "an entirely different mode of thought," Casas says. "Suddenly there was open-ended problem solving and a mantra of 'derive, don't memorize.'"

He says AP Physics was so challenging that he questioned his intent to study physics in college, which had been his plan. "After I started taking that physics class, I thought, 'no, no, no — maybe chemistry is for me.'"

In 2009, when he started college at Rutgers University in New Jersey, he initially enrolled as a chemistry student intending to specialize in chemical physics.

"When I started taking chemical physics courses at Rutgers, I was still taking Intro to Physics," he says. Taking physics again, with a different instructor, "healed the wounds I had from my AP physics experience," he says. He decided physics was still the best path toward a career focused on crystalline materials.

So, starting his sophomore year, he enrolled in the classes a physics major would need. But because he started his physics major "a year late," he always felt "a little bit on the outside," he says — unsure about his track.

As a senior, he finally took solid-state physics, the course in which majors learn to apply concepts in crystallography, quantum mechanics, and solid-state chemistry to solids and crystalline materials. "I finally really felt grounded. It gave me a good perspective on why I took this major to begin with," says Casas. "That motivated me enough to pursue graduate school."

Unfortunately, Casas' graduate school applications came back as rejections, but one school suggested he look into the APS Bridge Program.

"I had never heard of [the program] before. It was actually brand new," he says. "But when I looked into it, I could see how the program would help me bridge the gaps that I had." He says that because he hadn't developed many close relationships with faculty mentors during college, his grad school applications had fallen short, despite his good grades.

Casas submitted an application to the University of South Florida's Bridge Program in applied physics and was accepted immediately. "The Bridge Program offered a lot of mentorship, a lot of interactions with faculty members," he says.

Casas stayed at USF for two years, completing his master's on "exotic" behavior in magnetic insulator materials. He thought hard about whether the program was the right fit for his doctoral studies. By then, he had developed a deeper interest in an area of condensed-matter physics — "so-called heavy fermions, materials that contain F electrons," he says — that USF wasn't able to support experimentally.

Heavy fermion compounds are intermetallic materials that tend to contain elements from the F-block on the periodic table, down at the bottom. "They start to behave as if they're thousands of times heavier than they really are," says Casas, leading to "exotic behaviors." He was captivated.

Casas decided the University of California, Irvine, was a better fit. In 2015, he made the difficult decision to apply to a new doctoral program and uproot his life.

At UC-Irvine, his research was focused on looking for "signatures of exotic physics" in heavy fermion insulators, he says. He focused on samarium hexaboride, which exhibits different conductivity properties based on temperature.

Casas spent two years developing a method for measuring the thermal conductivity — a material's ability to transmit heat — of the crystals he was growing in the lab, while stretching them at extremely low temperatures. When he plotted his first set of data against the power law function predicted by theory, it "fit perfectly," he says.

"I'd finally ironed out the kinks. But that memory is slightly bittersweet, because two weeks later, the university shut down because of COVID," he recalls. "All experiments had to stop."

Eventually, Casas was able to return to the lab and collect enough data to graduate. In 2020, he landed a postdoc at the National High Magnetic Field Laboratory in Florida, where his research focused on a layered magnetic compound containing iron, germanium, and tellurium. The crystal is considered 'exfoliable' — the thin layers can be easily separated, creating 2D magnetic sheets, says Casas. The project leaned into his crystal growth and characterization skills. "It was a really nice culmination of all the work that I'd done up to that point," he says.

In April 2023, Casas accepted an offer from Coherent, where he's now working with silicon carbide — a material that's poised to impact the future of electric vehicles and the power grid.

"Being able to use what experience I have in crystal growth towards something that has societal impact is something I couldn't have imagined years ago," he says.

Liz Boatman is a staff writer for APS News.

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Yet many students are receiving minimal, if any, dedicated computing instruction in their physics courses. "Something like 50% of [physics] departments report that they're teaching computing," Caballero says. Based on discussions he's had with faculty across the country, he thinks this is an overshoot.

Caballero and five team members received the 2023 Excellence in Physics Education Award for their work for the Partnership for Integration of Computation into Undergraduate Physics (PICUP), a community of physics educators dedicated to adding computation into instruction. In 2022, Caballero was elected as an APS Fellow in recognition of his research.

Even in physics departments where students are receiving computing instruction, it may not be optimized for their success as future physicists. Caballero hopes to change that: Much of his work focuses on identifying ways that faculty can "organize the curriculum and the instruction so that people are learning computational things in physics," he says.

> "Embrace the use of open-source software," Caballero says. "Students can continue to use it forever."

For instance, he is examining how students effectively learn computing in groups, and he's working with collaborators to tackle qualitative questions about how students' see themselves as learners in physics. "What are their feelings towards this?" he says. "How do these environments that we create for them cause or interact with those outcomes?"

Taken together, those questions add up to one of Caballero's big ones: "How can we change the way that we do things holistically" to help students learn and build "a stronger positive sentiment towards computing in physics"?

One key takeaway from Caballero's research is that the best computing instruction in physics classrooms is consistent and intentional, not haphazard — no matter the level of instruction.

"If you're going to integrate computing into the classroom, [then] it needs to appear in every part of the class," Caballero says. Simply assigning projects that incorporate computing won't be effective if the instructor doesn't systematically equip students through classroom instruction and experiences to tackle those assignments. "If your course is structured in a way that has a presentation of material to students, time where they're practicing with that material, assessments where they are being told how well they do on that material — all of those things have to have computing," Caballero says.

However, constraints on time, technology, and budgets may limit what professors can add to their courses — especially if a department is starting from scratch, with no previous computing instruction.

In those situations, "starting small and growing the project over time is better than trying to do something large that is complicated and might not net you anything," Caballero says. For instance, on the PICUP website, instructors can access peer-reviewed exercise sets, like "Binary Stars with Equivalent One Body Problem," Snowboard Jumping and Newton's Second Law," and more. Caballero recommends that instructors try one of them, or pick out two or three to use in one semester. "That's starting small," he says.

Faculty can expect that projects will evolve over time to meet goals, expand, or morph in response to changing technology and students' needs. For instance, early in the COVID-19 pandemic, the shift to online instruction "was very, very challenging," Caballero says. "There was a lot of adaptation of the group-based dynamics, from classes where students were working together in classrooms with a computer and so forth, to students in virtual groups with a screen being shared."

Maximizing available resources can also make classrooms more equitable. "Embrace the use of open-source software," he says. "Students can continue to use it forever," and these free tools often can "do many of the cool things that some of the packages we pay for can do."

In some instances, not every student will have their own computer, or the university won't have enough for everyone. (That used to be the case at Caballero's university before a laptop policy was implemented.) It's still possible for students to be taught equitably. In the past, Caballero's department purchased enough laptops to provide one for every four students. "So that was the group size," he says. Students who had their own computers could still bring them, but this policy ensured that students who didn't own one still had access to computers.

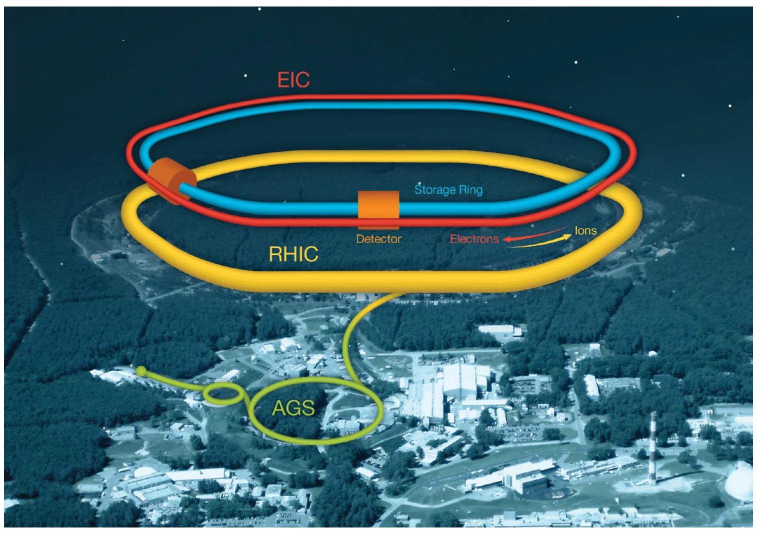
While keeping up with changes in computing technology can be challenging, it's also key to equipping physics students with the skills they need for their future careers. "Preparation with computing is just part of being a participant in physics," Caballero says. "If we aren't trying to keep up with the world that our students are encountering, we're not providing the best possible education that we can."

To future-proof your physics classroom with computational training, get free resources from PICUP at compadre.org/PICUP and the APS Effective Practices for Physics Programs (EP3) guide at ep3guide.org/guide/computational-skills.

Rachel Crowell is a math and science writer based in Iowa.

US Nuclear Scientists Chart Priorities for Next Ten Years

BY MITCH AMBROSE



The planned Electron-Ion Collider at Brookhaven Lab. A new electron accelerator (red) and electron storage ring (blue) will fit inside the tunnel that houses the Relativistic Heavy Ion Collider (yellow). Credit: Brookhaven National Laboratory

For the next ten years, two of the highest priorities of the US nuclear physics community are to construct an Electron-Ion Collider (EIC) and to pursue an international campaign to detect the hypothesized process of neutrinoless double beta decay (NDBD). These projects are endorsed in the Long Range Plan for Nuclear Science, published in October by the Nuclear Science Advisory Committee, which reports to the Department of Energy and National Science Foundation.

The plan was produced by a panel of nuclear scientists who spent over a year gathering community input and deciding priorities for research, facility construction, and workforce development. NSAC unanimously approved the plan on Oct. 4; it will now be a guidance document for the agencies and a tool for advocacy with Congress.

The previous iteration of the plan, published in 2015, also ranked the EIC and a hunt for NDBD as top priorities. Significant progress has been made on the EIC since then, with Brookhaven National Lab selected as the host site and preparation for construction underway. The facility is estimated to cost DOE around $2.4 billion to build and would begin operations in about a decade. The collider promises to provide unprecedented insight into the structure of protons, and it would help sustain a workforce capable of building and operating world-class particle accelerator facilities.

Meanwhile, the NDBD campaign remains in the early planning stages. If detected, the decay would indicate the neutrino is its own antiparticle, a discovery which could shed light on fundamental questions, such as why matter is more prevalent than antimatter in the universe. Given how difficult such a decay would be to detect, the plan endorses pursuing three distinct experiment concepts that have been in development: CUPID, nEXO, and LEGEND-1000. The US share of costs across all three experiments could total around $1 billion over ten years, according to a 2021 estimate.

DOE and NSF asked the panel to consider two budget scenarios: constant funding and 2% annual growth above inflation relative to the fiscal year 2022 budget for nuclear physics. The panel later added two more scenarios: 2% annual growth above inflation relative to the fiscal year 2023 budget and growth consistent with the CHIPS and Science Act, which proposes a more ambitious ramp-up.

The panel concludes it's possible to pursue the EIC and NDBD campaign in parallel even under the 2% growth scenarios, though it would require stretching out the project schedules, reducing operation funds for existing facilities, and deferring work on other potential projects. The plan highlights other proposed projects, too, such as upgrades to the Continuous Electron Beam Accelerator Facility at Jefferson Lab and the recently completed Facility for Rare Isotope Beams at Michigan State University.

The highest overall priority of the plan, ahead of pursuing NDBD and the EIC, is to "capitalize on the extraordinary opportunities for scientific discovery made possible by the substantial and sustained investments of the United States." This entails continuing "effective operation" of existing national user facilities for nuclear science, increasing the research budget, raising the salaries of graduate students to be commensurate with their cost of living, and expanding efforts "to ensure a safe and respectful [workplace] environment for everyone," the plan explains.

The plan only briefly discusses the outlook under the constant budget scenario, simply stating it "would sacrifice much of the new opportunities" presented in the report and result in "relinquishing US leadership in key areas of nuclear physics."

Mitch Ambrose is Director of FYI. Published by the American Institute of Physics since 1989, FYI is a trusted source of science policy news. Sign up for free emails at aip.org/fyi.

An APS Fellowship Shapes a Capitol Hill Career

BY TAWANDA W. JOHNSON

After a year on Capitol Hill, physicist Thomas Plumb-Reyes views science policy as his next frontier.

"I still love science, but I am much happier now learning about the science that other people did and not having to do it myself," said Plumb-Reyes, who just wrapped up a year as an APS Congressional Science Fellow in Washington, DC.

Plumb-Reyes worked in the office of Rep. Steve Cohen of Tennessee, and he recently parlayed that experience into his current role as a 2023 AAAS Executive Science and Technology Policy Fellow for the State Department's Office of the Special Envoy for Critical and Emerging Technology.

APS Congressional Science Fellows use their scientific knowledge to help members of Congress, few of whom have technical backgrounds, in the policymaking process. They complete a two-week orientation in Washington, DC, interview on Capitol Hill, and then choose a congressional office or committee to serve for a year — usually from September to August.

During his fellowship, Plumb-Reyes helped to write and introduce bills, and assisted local organizations in navigating the federal grant process.

"I tried to approach this year as, foremost, a learning experience," he said. "What one is able to accomplish in Congress in one year is influenced by so many things that are out of one's control."

Alexandra Schnelle, deputy chief of staff for Rep. Cohen, said Plumb-Reyes "made a significant impact" during his fellowship, "from his expertise on artificial intelligence" to his efforts "to determine the best ways to reform the Tennessee Valley Authority."

"One of the bills he worked on even successfully passed out of a committee," Schnelle added —a sometimes difficult feat in the House of Representatives.

Having a science background was helpful, said Plumb-Reyes. "There was a fair amount of overlap in skills that were useful for working in Congress and skills that I first developed as a scientist," he said, "including communicating complex ideas clearly and accurately and for a variety of different audiences."

He practiced his people skills, too. "I met so many smart, dedicated, and hardworking people in Congress who are sincerely trying to help make the world a better place," he said — even though "well-documented institutional and systemic issues remain."

Indeed, working in Congress can be challenging. "It's extremely unlikely you'll come in and, armed with just the right knowledge and citations, completely change anyone's mind on climate change or gender-affirming care," Plumb-Reyes said.

"But that doesn't mean there isn't still a lot of good work you can do on a vast number of important challenges facing the country and the world."

Applications for the next class of fellows are open until Dec. 1, 2023.

Tawanda W. Johnson is the Senior Public Relations Manager at APS.

Thomas Plumb-Reyes. Credit: American Physical Society

Course Restructure continued from page 1

erything but the approach was kept the same," Webb says. "I used the same material, the same homework problems, and they had the same teacher." The retake option was put in place by other teachers in four introductory physics courses for biological science majors. In all cases the students had no knowledge of how the classes would be organized when they signed up.

Paul and Webb found that students with backgrounds traditionally classed as underrepresented in physics received higher grades in the restructured versions of both courses. The concepts-first change eliminated the grade gap between underrepresented minorities versus everyone else. A grade gap persisted between men and women. On the other hand, the retake option eliminated the grade gap for women but not for underrepresented minorities as a whole.

As to why some structural changes benefited some groups more than others, Webb explains that each group likely faces different obstacles. Support for this view comes from previous studies showing that, on average, students who identify as women and as coming from an ethnic minority have more of a grade gap than those who claim only one of these identities. "We suspect this [finding] is just evidence that structural racism and structural sexism are different things and are probably largely due to different structures in the particular physics courses," Webb says. "What these course structures are and exactly how they work would be interesting to know but is beyond the scope of [this study]."

As for the grade-gap eliminations they do observe, Paul and Webb point to several possible explanations. The concepts-first approach, for example, increases student interaction with the fundamental ideas underlying the topics being studied. Likewise, the retake option improves understanding by entrusting students with the opportunity to learn from their mistakes, Paul says. "These methods both aim at increasing productive student engagement in an attempt to improve the courses for everyone," she adds.

"This [study] provides a clear example of how structure can make a difference, providing equity in classroom achievement," says Andrew Heckler, who studies physics education at the Ohio State University. That the team finds that this parity can be gained without changing the course content or the depth in which it is covered is particularly important, he adds. "It is common for us in the physics community to assume that improving equity means lowering standards. Sometimes this assumption is inadvertent and unnoticed, sometimes it is explicit. In any case, it is good to 'control' for this issue so that this [view] can be refuted."

Despite his excitement about the results, Heckler does offer a word of caution on extrapolating the outcome to all science classes. "This work looks at two course changes at one institution," he says. "The results need to be replicated many times at a variety of institutions and with a variety of instructors, populations, and course-structure changes before we can make general statements like 'changing the structure reduces inequity.'"

Paul and Webb agree that the results need to be replicated. But they and Heckler also note that some of that additional evidence already exists. For example, a recent study found significantly narrower achievement gaps in courses taught via "active-learning" methods, where the students engage in the course material through discussions or problem solving, than for those taught via traditional lecturing, where students sit and listen to the instructor. Traditional lecturing is the pedagogy of choice of most US universities, Webb says. But studies increasingly show it's a poor method for teaching any student.

Even with this growing evidence, the view persists that the students, and not the course, are the "problem" when it comes to differences in learning outcomes. Webb thinks that this attitude remains entrenched partly because change is difficult but also because physics educators have yet to be convinced of the findings. He and Paul hope that this study could be a tipping point in swaying opinions. Poor performance, particularly in introductory courses, is one of the biggest reasons that students — of all backgrounds — give for dropping out of science. "We should all want to rectify that," Paul says.

Katherine Wright is the Deputy Editor of Physics Magazine, *from which this article was reprinted.*

Summer REUs continued from page 3

magnetic fields, bombarding Earth and sometimes disrupting power grids.

Monroe spent the first half of the summer getting acquainted with the Hinode Solar Optical Telescope, a Japanese mission ("Hinode" means "sunrise") that has partnered with the United Kingdom and NASA — as well as 16 years' worth of raw data and a 1970s programming language, IDL.

"By the end of the program, I was proficient in and comfortable with an entirely new programming language," she says.

"The experience makes me think I want to do something more related to instrumentation, actually," says Monroe. "I found it really fascinating to gain visibility into the technology of the satellite I was working with, and to learn about its limitations."

As she gears up to search for her third internship, Monroe has advice for other physics majors.

"Start your [internship] search early — start during winter break or even fall break," she says. "Don't wait until January 20th and then realize all the deadlines are February 1st." Monroe suggests setting aside several hours to scroll through NSF's REU website. "Instead of thinking, 'what *should* I be interested in,' think about what you're actually interested in," she adds. "Then bookmark the projects that get you excited."

Monroe says she'll also think about where she'd like to live for a summer — she uses the location filter as she searches — and an internship's pay and start date. Department culture is important to her, so she'll consider the number of women faculty and scientists in the program before deciding on her top internship choices. Faculty pages are a great place to start.

Monroe says she realizes, in hindsight, that she took a risk by applying to just six opportunities last year, even though she landed her top choice. Because REUs offer decent summer pay and are a great résumé item for grad school applications, they tend to be highly competitive.

For next summer, Monroe plans to apply to even more internships. She suggests casting a wide net, "because some of the ones that you don't think you're qualified for, you might be exactly what they want. Some programs want somebody with no experience. They want to train you in."

When it comes to recommendation letters, Monroe says to make sure you ask early, to give professors and mentors enough time to write effective letters. And to get strong letters, only request them from "people who have seen [your] best work."

Then, if you land an offer next spring, get ready to do your own work. "Do all the things that you think a diligent student would do," Monroe says, like reading books to learn more about your project and familiarizing yourself with the journal literature. Monroe talked with her PI, Takeda, upfront about how often they would communicate.

For Monroe, the best part about a summer internship away from home isn't the knowledge you gain, but your growth as an independent person.

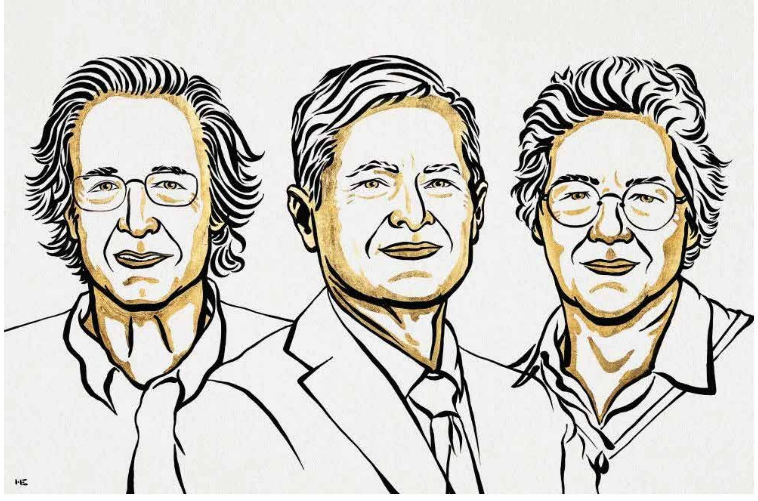
"It was my first time truly living alone across the country, with all new people," she says. "It gave me the confidence to come back to this semester feeling like I'm an adult, and the space to grow into the person I hoped I could become."

Visit aps.org/programs/education/undergrad/students to view APS programs and resources, search for an NSF-funded REU site, and more.

Liz Boatman is a staff writer for APS News.

Nobel Prize in Physics Awarded for Techniques to Produce Ultrashort Pulses of Light

Three scientists have received the prize for experimental work that allows researchers to probe the dynamics of electrons in atoms and molecules.



Pierre Agostini, Ferenc Krausz, and Anne L'Huillier. *Credit: Niklas Elmehed © Nobel Prize Outreach*

The Royal Swedish Academy of Sciences has awarded the 2023 Nobel Prize in Physics to Pierre Agostini, Ferenc Krausz, and Anne L'Huillier for "experimental methods that generate attosecond pulses of light for the study of electron dynamics in matter."

"The American Physical Society congratulates the 2023 physics laureates for their pioneering discoveries that paved the way for attosecond physics," said Jonathan Bagger, CEO of APS.

The Nobel Committee for Physics has split the prize equally among the three laureates: Agostini of Ohio State University, Krausz of the Max Planck Institute of Quantum Optics and Ludwig Maximilian University of Munich in Germany, and L'Huillier of Lund University in Sweden. The three physicists developed techniques to produce extremely short pulses of light that can be used to probe the minute dynamics of electrons in atoms and molecules.

"The laureates' achievements really get to the heart of what physics is about — understanding how the world works on extremely short time scales," said Robert Rosner, president of APS. "It's excellent experimental work that opened doors to new applications as well as furthered our fundamental understanding of matter."

The behavior of electrons can change on short notice — as short as a few tenths of an attosecond. An attosecond is 1 x 10-18 second, or one billionth of a billionth of a second. The number of attoseconds in one second is roughly the same as the number of seconds since the start of the universe. Attosecond physics uses light pulses that last for as short as a few hundred attoseconds to study the interactions of light and matter on tiny scales.

The laureates' contributions to techniques for producing attosecond light pulses have allowed researchers to examine ultrafast electron behaviors that couldn't be studied before. Attosecond physics could give rise to diverse applications, including very fast electronics, by allowing a material to switch from being an insulator to a conductor extremely quickly, and early detection of disease in a biological sample, by looking for changes at high time precision.

All three laureates have published work in APS's Physical Review journals. L'Huillier is an APS member and APS Fellow and has been recognized by APS's Outstanding Referees program.

The Nobel Committee has cited five papers from Physical Review Letters and one paper from Physical Review A in the scientific background on the 2023 physics prize. This marks the 13th consecutive year that the Nobel Committee has cited laureates' papers in the Physical Review journals as central to the physics or chemistry awards. APS has made these papers — Agostini et al. 1979, L'Huillier et al. 1982, Schins et al. 1994, Lewenstein et al. 1994, Antoine et al. 1996, Bellini et al. 1998 — free to read online.

The prize includes the equivalent of 1 million US dollars, to be shared equally among the recipients.

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ees' feedback. He says he found the expertise shared on program evaluation to be especially helpful, as he gears up for his next big journey: a doctorate in particle physics outreach and education.

"Only a minority of kids will grow up to become scientists," he says. "Yet they can all benefit from an understanding and appreciation of science."

Interested in meeting others in informal physics education, or hearing tips for designing and evaluating outreach activities? JNIPER's final coffee hours of 2023 are scheduled for Nov. 29, 12 - 1:30 p.m. ET, and Dec. 20, 1 - 2:30 p.m. ET. Register at aps.org/programs/outreach/jniper.

Liz Boatman is a staff writer for APS News.

University in India Celebrates a Second Successful Round of REUs

A student presents his REU project. *Credit: Sultana N. Nahar*

In the United States, Research Experiences for Undergraduates, or REUs, are coveted opportunities for students to gain research experience. Now, a team of scientists is working to bring REUs to Indian institutions, which don't offer them.

This summer, an REU initiative at India's Aligarh Muslim University (AMU) celebrated its second successful class of students, who just wrapped up six-month REUs. The 36 students in "REU 2" worked in diverse science and engineering fields from October to May, under the guidance of AMU faculty who volunteered to advise the students. The students wrote and defended theses, some of which have been accepted for presentations in national conferences.

"REU 2" builds on the success of the first round of REUs in 2019, which supported 26 students and led to two papers being published in refereed journals. (The COVID-19 pandemic delayed the second round until last fall.)

The REU initiative — the first at an Indian university — was spearheaded by Sultana N. Nahar, an astronomy professor at the Ohio State University (OSU). The initiative is administered through the Indo-US STEM Education and Research Center of OSU and AMU, which Nahar and OSU astronomy professor Anil Pradhan co-founded in 2013.

"The success of the two REU programs at Aligarh Muslim University should pave the way for other Indian universities," says Nahar, who hopes the initiative will help students in India build a path toward admission to US universities and, eventually, careers in scientific research.

Granville History continued from page 2

in *Scientific American*, Woods had also worked on many other ideas, including a steam boiler furnace, an electromagnetic brake, and several telephonic devices.

But the article kicked his induction telegraph efforts into high gear. He applied for a patent on May 21, 1885, secured funding from a local dentist, built a ten-foot-long model train track to show it off with, and had it tested by telegraph operators.

Several months later, the patent office replied. Phelps had filed on Feb. 20, 1885 — a day before the article was published, and three months before Woods. But because neither man had been actually granted the patent yet and the US operated under a "first-to-invent" rather than "first-to-file" system at the time, the two parties went to court to establish priority.

Woods and his lawyer produced documents and witnesses testifying he created the invention in 1881, while Phelps could not prove he did earlier than October 1884. The judge ruled in Woods' favor, and after an appeal from Phelps was struck down, he finally received the patent for the induction telegraph system on Nov. 29, 1887.

According to Fouché, at least 17 of the 45 patents filed by Woods over his lifetime would be involved in court proceedings, including his idea for a third rail to power electric subway trains from below. And when he died in 1910 from smallpox complications, he was buried in an unmarked grave. He struggled financially, professionally, and personally throughout his life, writes Fouche. "The experiences of Granville Woods have shown how … a great idea does not necessarily guarantee success."

In recent decades, Woods' legacy has been reinvigorated. He was honored with a commemorative New York City subway MetroCard in 2004 for his contribution to the third rail system. In 2006, he was inducted into the National Inventors Hall of Fame, only the second Black inventor to receive the distinction. And in 1975 — 65 years after the inventor's death — Woods' unmarked gravesite in Queens, New York, was finally given a headstone. An article in *The New York Times* quoted a historian, M.A. Harris, who attended the ceremony.

"There had been no research done on Woods since 1887," Harris said. "Yet this man had performed such magic."

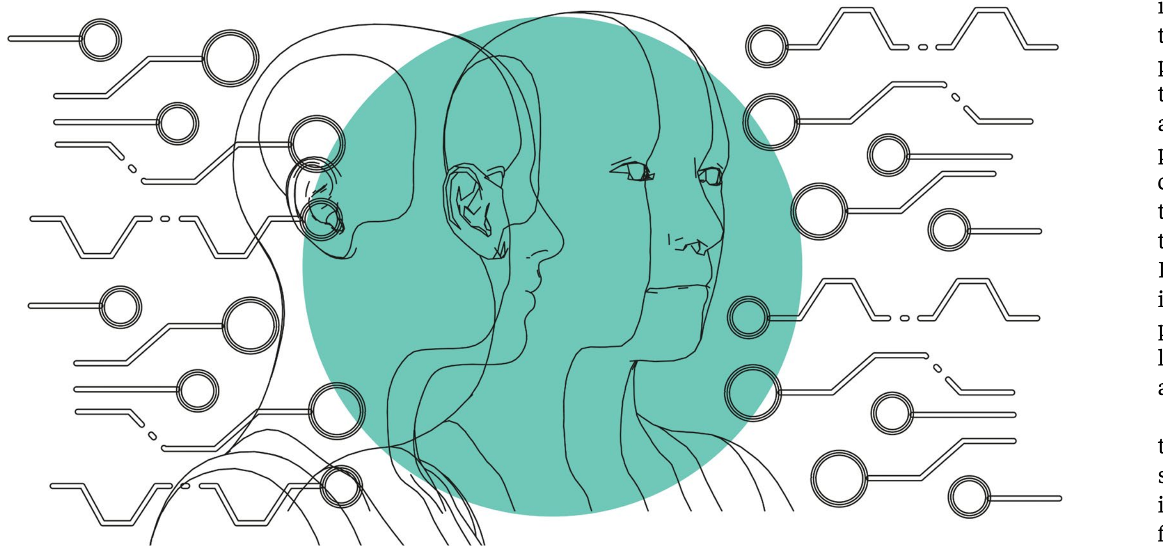
Tess Joosse is a science journalist based in Michigan.

THE BACK PAGE

The Rise of the Data Physicist

In the search for new physics, a new kind of scientist is bridging the gap between theory and experiment.

BY BENJAMIN NACHMAN



Traditionally, many physicists have divided themselves into two tussling camps: the theorists and the experimentalists. Albert Einstein theorized general relativity, and Arthur Eddington observed it in action as "bending" starlight; Murray Gell-Mann and George Zweig thought up the idea of quarks, and Henry Kendall, Richard Taylor, Jerome Freidman, and their teams detected them.

In particle physics especially, the divide is stark. Consider the Higgs boson, proposed in 1964 and discovered in 2012. Since then, physicists have sought to scrutinize its properties, but theorists and experimentalists don't share Higgs data directly, and they've spent years arguing over what to share and how to format it. (There's now some consensus, although the going was rough.)

But there's a missing player in this dichotomy. Who, exactly, is facilitating the flow of data between theory and experiment?

Traditionally, the experimentalists filled this role, running the machines *and* looking at the data — but in high-energy physics and many other subfields, there's too much data for this to be feasible. Researchers can't just eyeball a few events in the accelerator and come to conclusions; at the Large Hadron Collider, for instance, about a billion particle collisions happen *per second*, which sensors detect, process, and store in vast computing systems. And it's not just quantity. All this data is outrageously complex, made more so by simulation.

In other words, these experiments produce more data than anyone could possibly analyze with traditional tools. And those tools are imperfect anyway, requiring researchers to boil down many complex events into just a handful of attributes — say, the number of photons at a given energy. A lot of science gets left out.

In response to this conundrum, a growing movement in high-energy physics and other subfields, like nuclear physics and astrophysics, seeks to analyze data in its full complexity — to let the data speak for itself. Experts in this area are using cutting-edge data science tools to decide which data to keep and which to discard, and to sniff out subtle patterns.

Machine learning, in particular, has allowed scientists to do what they couldn't before. For example, in the hunt for new particles, like those that might comprise dark matter, physicists don't look for single, impossible events. Instead, they look for events that happen more often than they should. This is a much harder task, requiring data-parsing at herculean scales, and machine learning has given physicists an edge.

Nowadays, the experimentalists who manage the control rooms of particle accelerators are seldom the ones developing the tools of machine learning. The former are certainly experts; they run colliders, after all. But in projects of such monumental scale, nobody can do it all, and specialization reigns. After the machines run, the data people step in.

The data people aren't traditional theorists, and they're not traditional experimentalists (though many identify as one or the other). But they're here already, straddling different camps and fields, proving themselves invaluable to physics.

For now, this scrappy group has no clear name. They are data scientists or specialized physicists or statisticians, and they are chronically interdisciplinary. It's high time we recognize this group as distinct, with its own approaches, training regimens, and skills. (It's worth noting, too, data physics' discreteness from computational physics. In computational physics, scientists use computing to cope with resource limitations; in data physics, scientists deal with data randomness, making statistics — what you might call "phystatistics" — a more vital piece of the equation.)

Naming delivers clout and legitimacy, and it shapes how future physicists are educated and funded. Many fields have fought to earn this recognition, like biological physics, sidelined for decades as an awkward meeting of two unlike sciences — and now a full-fledged and vibrant subfield.

It's the data wranglers' turn. I propose that we give these specialists a clear identity — the "data physicists." Unlike a traditional experimentalist, a data physicist probably won't have much hands-on experience with instrumentation. They probably won't spend time soldering together detector parts, a typical experience for experimentalists-in-training. And unlike a theorist, they may not have much experience with first-principles physics calculations, outside of coursework.

But the data physicist *does* have the core skills to understand and interrogate data — complete with a strong foundation in data science, statistics, and machine learning — as well as the computational and theoretical background to relate this data to underlying physical properties.

The data physicists have their work cut out for them, given the enormous amount of data being churned out by experiments in and beyond high-energy physics. Their efforts will, in turn, improve the development of new experimentation methods, which are today often developed from simpler, synthetic datasets that don't map perfectly to the real world.

But this data will go underutilized without a skilled cohort of scientists who can deftly handle it with new tools, like machine learning. In this sense, I'm not merely arguing for name recognition. We need to identify *and then train* the next generation, to tackle the data we have right now.

How? First, we need the right degrees: Universities should develop programs explicitly for data physicists in graduate school. I expect the data physicist to have a strong physics background *and* extensive training in statistics, data science, and machine learning. Take my own path as a starting point: I studied computational aspects of particle theory as a master's student and took many courses in statistics as a PhD student, which led to naturally interdisciplinary research between physics and statistics/machine learning — and between theorists and experimentalists.

The right education is a start, but the field also needs tenure-track positions and funding. There are promising signs, including new federal funding to help institutions launch "Artificial Intelligence Institutes" dedicated to advancing this research. But while investments like this fuel interdisciplinary research, they don't support new faculty — not directly, at least. And if you're not at one of the big institutions that receive these funds, you're out of luck.

This is where small-scale funding must step in, including money for individual research groups, rather than for particular experiments. This is easier said than done, because a typical group grant, which a PI uses to fund themselves and a student or postdoc, forces applicants to adhere to the traditional divide: theory or experiment, or hogwash. The same goes for the Department of Energy's prestigious Early Career Award — there is no box to check for "interdisciplinary data physics."

As tall an order as this funding is, it could be easier to achieve than a change in attitude. Physicists might well be famous for many of humanity's greatest discoveries, but they're also notorious for their exclusionary, if not outright purist, suspicion of interdisciplinary science. Physics that borrows tools and draws inspiration from other fields — from cells in biological physics, say, or from machine learning in data science — is often dressed down as "not real physics." This is wrong, of course, but it's also a bad strategy: A great way to lose brilliant physicists is to scoff at them.

Not all are skeptical; far more, in fact, are excited. Within APS, the Topical Group on Data Science (GDS) is growing rapidly and might soon become a Division on Data Science, a reflection of the field's growing role in physics. My own excitement about working directly with data inspired me to become an "experimentalist" myself, although I realize now how restrictive that label was.

As available data grows, so does our need for data physicists. Let's start by calling them what they are. But then let's do the hard work: educating, training, and funding this brilliant new generation.

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The author wishes to thank the Editor, Taryn MacKinney, for her work on this article, and David Shih for coining the term 'data physicist' at a recent Particle Physics Community Planning Exercise.

Valley Prize continued from page 1

of the black hole and, in particular, has nothing to do with the matter than formed the black hole in the first place," Penington says. "If you looked at the final state of the radiation, you couldn't reverse engineer the initial state of matter."

This paradox puzzled theorists for decades. No one could point to an error or missing factor in Hawking's calculation. Still, the idea that the final state of a system doesn't in any way depend on its initial state was inconsistent "with every other law of physics that we know," says Penington.

Eventually most scientists conceded that information about the black hole had to be preserved, even if the mechanism was unknown. Then, in 2019, two independent papers went up on arXiv on the same day — a single-author paper by Penington and one by Ahmed Almheiri et al. — that brought some resolution.

The papers, published later in the *Journal of High Energy Physics*, presented a more complete version of Hawking's calculation and a result consistent with information being preserved. In a follow-up paper about six months later, Penington demonstrated that such information could be preserved through a spacetime wormhole. These papers formed the basis for his PhD thesis and ongoing research as an assistant professor at the University of California, Berkeley.

Theoretical work seems to come naturally to Penington, but he's not one to stare at a blank piece of paper. "Ideas come out of lots of conversations with people at blackboards," he says. "Just you explaining things to them and them explaining things to you."

> "We just keep being surprised by how much gravity knows," Penington says.

He also finds that letting ideas percolate in his subconscious pays off — although not always at opportune moments. When he got the idea that led to his first pivotal paper, Penington realized that if the idea worked, it would *really* work. He tried not to be too preoccupied during a subsequent month-long vacation with friends but was only partly successful. "This was by far the most interesting thing I'd ever thought about," he says.

What captivates Penington about theoretical physics is what he calls the simple, obvious idea. "We have two theories that describe nature, and there must, at some level, be one theory," he says. Finding a set of self-consistent rules, a basic algorithm of the universe, would be a milestone for humanity, he says.

Experimental results — from, say, smashing together particles at the Planck scale — might speed up the process, but step one is to identify a consistent, complete theory that we understand mathematically, Penington says. "Getting to that, even if it isn't the right one, would still be a breakthrough."

To get there, Penington says theorists will need to be bolder than ever. "The traditional story is that just adding quantum mechanics and gravity together doesn't really work very well, except for in very simple things, and that we need to go to some fancy idea — string theory or something like that — to make sense of it all. And in the last ten years, we just keep being surprised by how much gravity knows," he says. At some point we'll need those fancy ideas, but "I think that's got to wait around while we're using just gravity to learn more," he says.

In the meantime, Penington is keeping a close eye on quantum cosmology. Anytime there is progress on black holes, he wonders what it can reveal about the Big Bang or cosmological horizons. In the next ten years, "possibly the most exciting thing that could happen would be some real insight into how to think about quantum gravity and cosmology," he says.

When he's not talking to colleagues at a blackboard or in the office, Penington is usually on an outdoor adventure — rock climbing, skiing, hiking, or windsurfing. "Doing physics and really getting into wilderness have a similar appeal," he says. "It's the feeling of connection to nature, but also the feeling of exploration, and the feeling of not knowing what you're going to find. There's something deeply exciting about that."

Kendra Redmond is a writer based in Minnesota.