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APS physics

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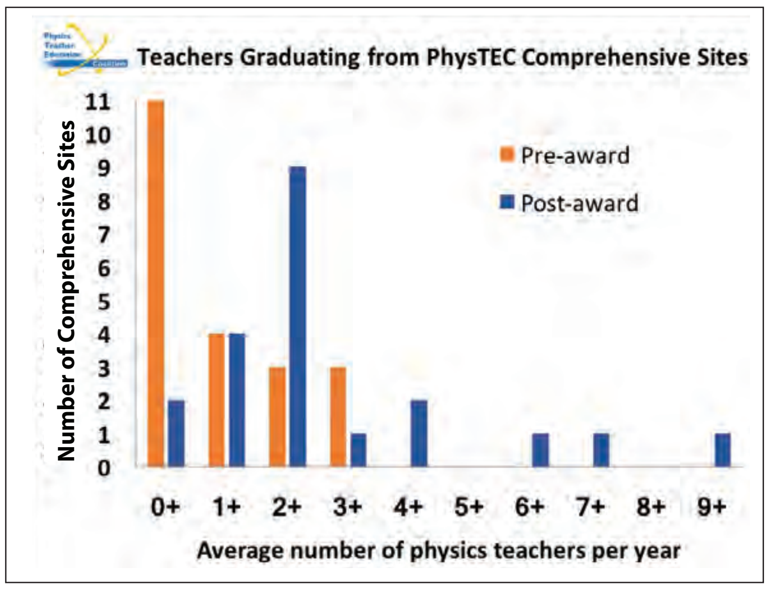
PhysTEC Sites Triple Number of Qualified Teachers

By Rachel Gaal

"What do you want to be when you grow up?" Children asked this age-old question might succeed in their aspirations, taking the classes in school that interest them and align with their goals. But when it comes to those who are pursuing careers in physics, many might decide by their first physics class (if they are offered one before college at all) that this field isn't for them.

While the number of students pursuing physics and STEM degrees is increasing, some might not be exposed to the true beauty of physics in high school, in part because thousands of teachers are not adequately prepared to teach physics in the U.S. Out of more than 13,000 physics teachers, 63 percent have no major or minor in physics or are not certified, according to a recent report commissioned by the APS Panel on Public Affairs. In the U.S., only about 40 percent of high school graduates in the class of 2014 were enrolled in at least one physics course before college, and only 26 percent of high school seniors who expressed interest in a STEM major met a benchmark showing them prepared to be successful in a rigorous higher education STEM discipline.



"Many of the best opportunities in the United States for challenging and rewarding jobs will require mastery of subjects such as computer science and physics," said Michael Marder, a physicist at the University of Texas, in the APS press release of the STEM report. "Every student in every high school deserves a great teacher in these fields—but right now the teachers are simply not enough."

These are some of the many statistics that motivate the Physics Teacher Education Coalition, (PhysTEC), to fund interested universities around the nation to recruit and prepare physics teachers in new and innovative ways.

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Hitting the Streets to Support Science

On April 22, marchers gathered in over 600 locations to rally for science. The Washington DC March for Science was endorsed by APS along with more than 200 other organizations. Tens of thousands of people came to the Washington Monument on the National Mall to hear speakers, carry banners and signs, and call for evidence-based policymaking and robust science funding. For more photos see p. 7

APS and CERN Sign Open Access Agreement

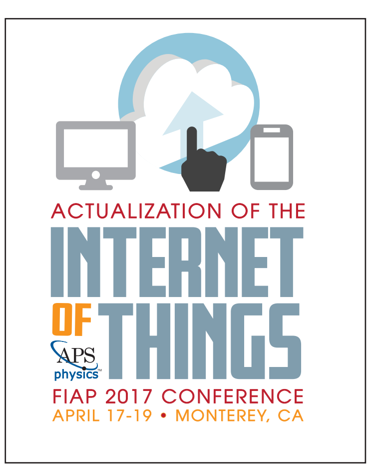
The APS Board of Directors voted on April 23 to enter into an agreement with CERN to participate in the Sponsoring Consortium for Open Access Publishing in Particle Physics (SCOAP3). The agreement covers three journals published by APS – *Physical Review Letters*, *Physical Review D*, and *Physical Review C*. Under this agreement, which starts January 1, 2018, authors of high energy physics articles will bear no direct cost to publish articles open access in these journals. For more visit go.aps.org/2qiOBx1

Building an Internet of Things

By Jessica Thomas

Some weird stuff is online these days. From a swallowed pill, to a sheet beneath a rustling baby, to a New England tomato, each can now transmit data about its surroundings to the cloud.

Welcome to the brave new world of the Internet of Things (IoT) in which networks of sensors relay information about the physical world to "smart" machines that analyze and interpret the data. The IoT could revolutionize the way factories are run, how health care is delivered, and the future of transportation.



This potential—and the scientific advances that are needed to make it a reality—were presented in April at the Actualization of the Internet of Things conference in Monterey, California. The first-of-its-kind meeting organized by the APS Forum on Industrial & Applied Physics brought together roughly 60 engineers, entrepreneurs, and scientists.

A meeting like this is timely. By 2020, it is estimated that more than 20 billion devices will be connected to the internet. And within a decade the economic impact of the IoT could reach $11 trillion per year.

Part of what's driving the IoT is the proliferation of high-quality detectors, such as cameras and chemical sensors. These can be distributed in cities and power plants, on land or in the sky, acting as high-resolution "eyes" and "noses" that surpass human capabilities.

"The physical world is being digitized," said Heike Riel, the director of physical sciences research at IBM in Zurich.

Riel gave the example of "precision agriculture," in which farmers rely on satellite data to control

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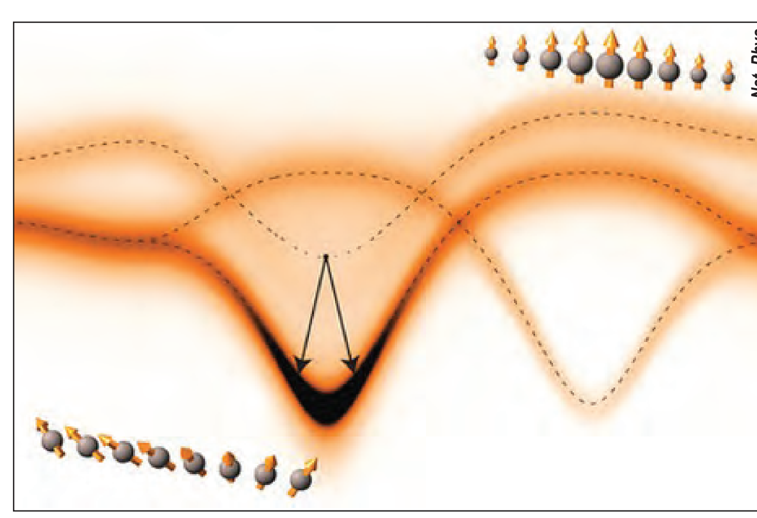
Research News: Editors' Choice

physics.aps.org

A Monthly Recap of Papers Selected by the Physics Editors

Magnetic Material Mimics Higgs Decay

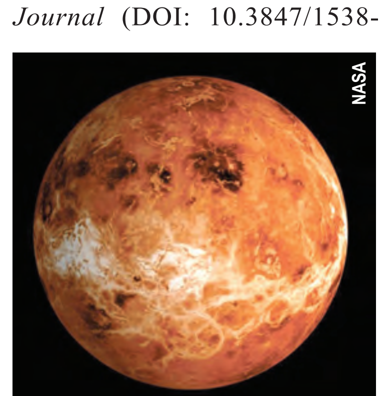
A two-dimensional antiferromagnetic material could provide a condensed-matter analog for the physics of Higgs boson decay, according to a report by Jain et al. in *Nature Physics* (DOI: 10.1038/nphys4077). Researchers are increasingly looking into condensed-matter systems to find ways to observe otherwise inaccessible physics, from the emission of Hawking radiation to the formation of Majorana fermions. Higgs-like behavior has previously been found in materials close to the critical point of a quantum phase transition, such as superconductors and quantum magnets. Jain et al. have now found a magnetic system that could potentially simulate an important aspect of Higgs physics: the ultrafast decay of the Higgs into other particles. The researchers studied the two-dimensional antiferromagnet Ca_2RuO_4. By observing the material's scattering of spin-polarized neutrons, the team provided evidence for magnetic excitations, or quasiparticles, that behave like the Higgs. They then showed that these Higgs-like quasiparticles quickly decayed into modes reminiscent of other standard-model particles called Goldstone bosons. The approach could help researchers bring the complex physics of Higgs dynamics into the range of tabletop experiments.



A two-dimensional magnetic system hosts quasiparticles whose decay mimics that of the Higgs boson.

A New Venusian Look-Alike

A new member of the exoplanet club is sparking excitement in the astronomical community. Angelo et al. published in *The Astronomical Journal* (DOI: 10.3847/1538-3881/aa615f) their discovery of an object 219 light years from Earth—Kepler-1649b—that is strikingly similar to our bright sister planet, Venus. With the help from the Kepler mission transit data and observations from the Mount Palomar Observatory in California, the team was able to analyze the flux of radiation onto the planet and the planet's radius, concluding that the size and the amount of radiation it receives from its sun is consistent with the values for Venus. This Venus doppelgänger has a few notable differences, however. Kepler-1649b takes just nine days to orbit around a sun that's one quarter the size of our own. The group noted that by default the planet must travel much closer to its pint-sized host star to receive the amount of radiation comparable to Venus. This might subject the planet to solar flares, coronal mass



Venus may have a twin sister

RESEARCH continued on page 7

Easing the Heartache with Magnetic Fields

By Rachel Gaal

2017 APS March Meeting—Following the cures for common diseases in the early 1900s, life expectancy shot up by 20 to 30 years. But living longer has inadvertently created a new set of burdens, especially on the human heart. The complete prevention of vascular disease still remains elusive, and reigns as the leading cause of death since the 1930s. While modern medicine has decreased the heart disease mortality rate — from 64% of total deaths in 1979 to 23% of total deaths in 2014 — heart attacks are still responsible for one in four deaths in the U.S., and strokes are the fifth leading cause of death today.

Aspirin has long been prescribed to ward off a heart attack in those patients who have not yet had one, but there are limitations to the use of this therapy, according to physicist Rongja Tao of Temple University.

"Currently, many people take medicine to reduce blood viscosity, but it can cause serious side effects. From a physics point of view, when viscosity is decreased, the turbulence of the blood flow gets worse … and turbulent [circulation] puts much stress on the heart … we need a new technology to suppress both simultaneously."

At the APS March Meeting, Tao described how exposing a cardiac patient to an intense magnetic field can provide surprisingly long lasting reduction of blood viscosity, with a corresponding drop in blood pressure. This new approach to blood thinning that he is investigating has brought together scientists from the medical and physics departments at Temple University, and has grown in momentum due to its innovative take on combatting heart disease.

"Because of the iron in the red blood cells, [they] are sensitive to magnetic fields," explained Tao. "If we apply a strong magnetic field parallel to the [blood] flow direction, the red cells polarize, and they form short chains." Tao calls this magnetorheology (MR) technology a "promising treatment" for those who are susceptible to heart attack and stroke.

When the cells aggregate into chains, the viscosity of the flow becomes anisotropic, meaning here that the viscosity depends upon the relationship between the direction of the blood flow and the direction of the applied magnetic field. To suppress the turbulence, Tao said, the lower viscosity must be parallel to the blood flow to keep the circulation as laminar as possible. Accordingly, the magnetic field is applied parallel to a major artery. The higher viscosity is then perpendicular to the flow, which reduces the side effect of turbulence and keeps the chains toward the center of the artery.

"Before a magnetic field [is] applied, the [red blood] cells were randomly distributed in the plasma," he described. "Then you apply a magnetic field, at about

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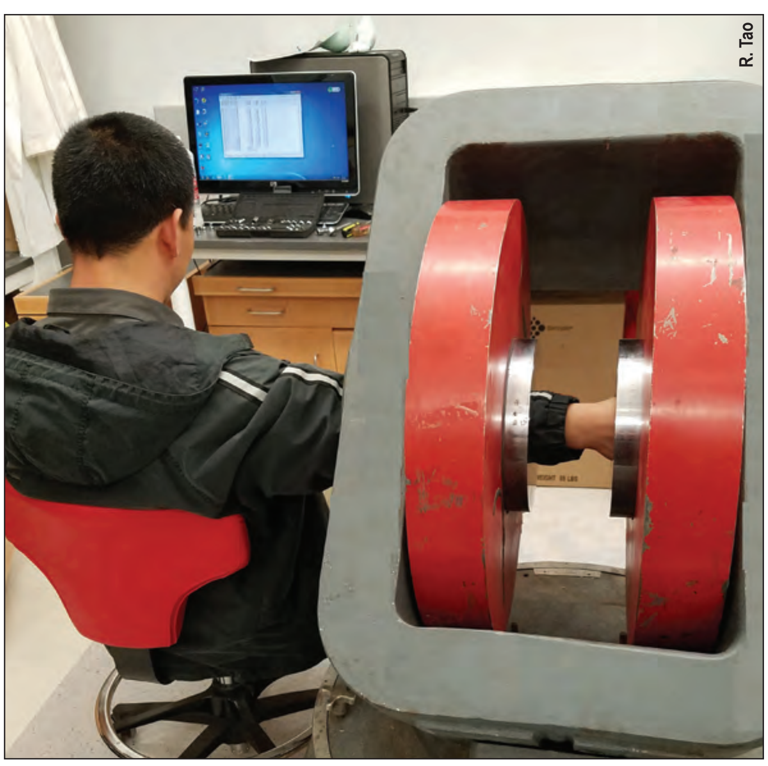


Researchers saw a long-lasting drop in blood pressure following exposure to high magnetic fields.

This Month in Physics History

May 7, 1959: C.P. Snow Gives His "Two Cultures" Lecture

Many scientists over the years have lamented how little interest in science (if not outright hostility to it) the average person shows—including many highly educated academics in the humanities. This notion has its roots, in part, in a famous lecture and subsequent book by a British physical chemist named Charles Percy (C. P.) Snow.

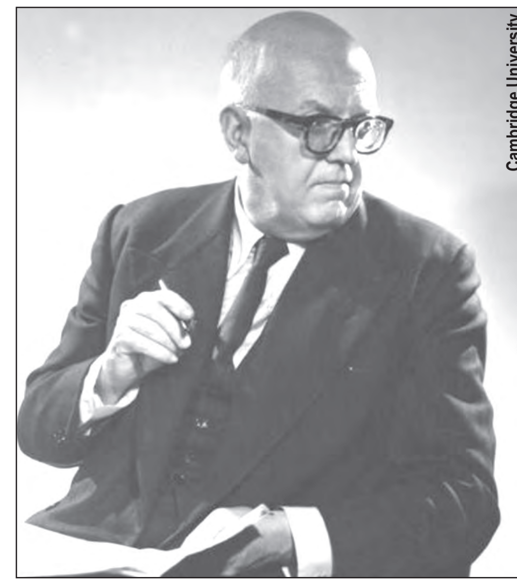
Snow was born in 1905 in Leicester, England, where his father, William, was a church organist and choirmaster who supplemented the family income by giving music lessons and working as a clerk in a shoe factory. What his childhood lacked in wealth, it made up for in intellectual richness, and thanks to scholarships, the young C.P. was able to attend the nearby university. The lure of financial stability drew him into science, although his literary inclinations were also evident. He wrote a novel as an undergraduate—and then destroyed it. After earning a degree in chemistry and a master's in physics, he went on to complete a Ph.D. in physics from Christ's College, Cambridge, and became a Fellow there in 1930.

Snow's dissertation investigated the infrared spectra of simple diatomic molecules, and he continued to work in that area along with using crystallographic methods to study complex organic molecules. He published his first novel—–a mystery called *Death Under Sail*—in 1932. With a colleague, Philip Bowden, Snow stumbled upon on a potentially promising new technique for synthesizing vitamin A, which might have cemented his scientific reputation, had their published paper not contained a clear, critical error.

That experience, and Snow's background in molecular physics in general, found its way into the author's 1934 third novel *The Search*. The book follows a scientist from his childhood discovery of science to a thriving research career and the promise of true greatness—until a single mistake in a calculation costs him a prestigious academic appointment, and he decides to leave the field.

Snow, too, opted to leave science, due in part to his embarrassment at the error, but also because his reputation as a novelist was on the rise around the same time: *The Search* received widespread critical praise. He concluded that perhaps he was not cut out for science after all, although his academic background would continue to influence his writing, both fictional and nonfictional. Snow remained at the college as an administrator and tutor, later serving as editor of the Cambridge Library of Modern Science, and also did a stint as editor of the popular science magazine *Discovery* from 1937 to 1940. As a novelist, he is best known for a series of 11 novels, *Strangers and Brothers*, published over 30 years.

With the outbreak of World War II, Snow put his scientific background to good use as director of technical personnel for the Ministry of Labour. He trained scientists in the new radar technology, and advised on the selection of British physicists to work on the fledgling Manhattan Project in the United States. Postwar, he divided his time between writing and serving as a government science advisor. He was knighted in 1957, became Baron Snow of Leicester in 1964, and served as secretary in Parliament for the newly formed Ministry of Technology in the House of Lords from 1964 to 1966.



Charles Percy Snow.

In May 1959, Snow was asked to give the prestigious Rede Lecture at Cambridge's Senate House, and he chose to deliver a harsh assessment of the British educational system, particularly with regard to what he saw as a marked preference for the humanities over science. In 1956, Snow had published an article in the *New Statesman* entitled "The Two Cultures," and this formed the basis for his talk. The "two cultures" of the title refers to what Snow called a "gulf of mutual incomprehension" between the sciences and the humanities, making true communication between them very difficult.

As an example, he pointed to the countless times at social gatherings of intellectuals, when those in the humanities would decry the supposed illiteracy of scientists. Snow invariably responded by asking how many could describe the second law of thermodynamics. "The response was cold: it was also negative," he wrote. "Yet I was asking something which is the scientific equivalent of saying, *Can you read?*" (The incident was immortalized by satirists Flanders and Swann in a musical monologue in 1964.)

In Snow's eyes, this cultural gap was a significant problem, driving many intellectually gifted people away from the sciences, which he deemed critical to solving what he saw as the most important issue facing the world: the huge inequality gap between the very rich and the very poor brought about by the industrial revolution. He expanded on the talk in a book later that year: *The Two Cultures and the Scientific Revolution*.

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News from the APS Office of Public Affairs

APS Student Members Share Research with Staffers of Louisiana Senators

By Tawanda W. Johnson

While in New Orleans for their 2017 APS March Meeting poster session, APS student members were thrilled to discuss their research with staffers from the offices of Louisiana Sens. Bill Cassidy (R-La.) and John Kennedy (R-La.).

"I very much enjoyed the opportunity to educate the Senate staffers on Louisiana's relationship to agencies such as NSF [National Science Foundation] and DOE [Department of Energy], using my personal experiences," said Noah Rahman, a student at Tulane University whose research could impact the next generation of solar cells.

The students met with staffers Rachel Perez and Mary Schlesinger in Cassidy's and Kennedy's offices, respectively. For about an hour, the students provided an overview of their research and offered details on the potential impact of their work. Perez and Schlesinger asked about the unique scientific research facilities in Louisiana, including the synchrotron at Louisiana State University's Center for Advanced Microstructures and Devices. The staffers also expressed interest in the applications of the students' research (one involved oil cleanup in the Gulf), and inquired about the students' education experiences in physics.

"Our meeting with the Senate staffers provided a unique opportunity for graduate students from Louisiana's universities, like me, to present our work and showcase how important our training and experiences are that we receive from our education," added Paul Abanador, a student at Louisiana State University. Abanador's research could potentially allow scientists to probe and control chemical reactions in new ways.

"I really appreciated the opportunity APS gave me to meet and discuss my research with the Senate staffers. As a graduate student, it is essential to not only focus on the research, but also to see the bigger picture. After my discussion with the Senate staffers, I now have a more comprehensive understanding of the social and economic impact of our research," said Zhi Zheng, a research assistant at the Advanced Materials Research Institute at the University of New Orleans. Zheng's research could help develop energy storage systems to mitigate the effects of climate change.

"A terrific way for congressional staff to recognize the value of science is to hear about it from an enthusiastic scientist who is doing research in their state or district," said Francis Slakey, interim director of the APS Office of Public Affairs (OPA).

Greg Mack, government relations specialist, said the APS OPA would like to arrange similar meetings between students and congressional staffers during future APS meetings.

"This meeting between the students and staffers during this March Meeting was a first of its kind for the APS OPA. We are happy with the outcome and look forward to having similar meetings in the future. It is crucial that both students and staffers discuss and understand the positive impact that research has on our society," he said.

APS members interested in meeting with their representatives in the U.S. Congress can contact Greg Mack at the APS Office of Public Affairs at mack@aps.org

Paul Abanador discusses his research with Mary E. Schlesinger (second from left) and Rachel Perez (third from left) as Greg Mack listens.

2017 National High Magnetic Field Laboratory Open House

Every year since 1994, the National High Magnetic Field Laboratory in Tallahassee, Florida, has hosted an open house, welcoming thousands of visitors to the facility. Scientists are treated like superstars, arriving in limousines and entering on a red carpet.

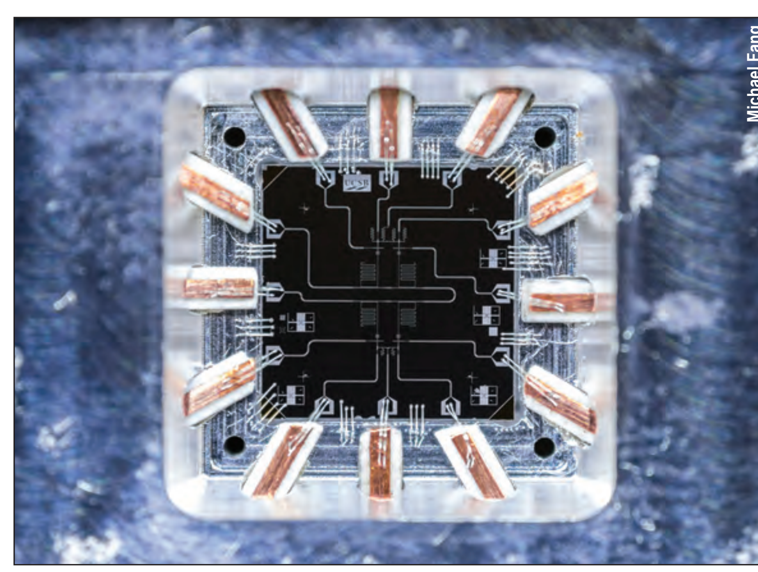
(Top L-R): The "MagLab" on Open House day; 2017 APS President and MagLab Chief Scientist Laura Greene signing autographs; photo-ops with the scientists are a huge hit.

(Bottom L-R): Laura Greene shows off the MagLab's largest bore magnet, which is big enough to take detailed MRI pictures of a rat. Kids were then able to see the amazing pictures of a beating rat heart and compare them to an MRI of a human heart; People line up well before doors open to see demos of vacuum chambers, sparking Tesla coils, and learn how magnets are magic; youngsters love getting to see the equipment up close in action.

Big Plans Ahead For Quantum Computing

By Sophia Chen

The first quantum computers are on the way. Bright and early on the first day of the 2017 APS March Meeting in New Orleans, researchers from Google, Microsoft, and Harvard University discussed their recent successes and their near-term plans for this nascent technology to a room crammed full of physicists.



A 2014 prototype of a Google qubit (0.6 cm by 0.6 cm) known as a transmon, based on superconducting circuits. Google's quantum computing test will use 49 updated versions of these qubits.

John Martinis, one of Google's quantum computing gurus, laid out the company's "stretch goal": to build and test a 49-qubit ("quantum bit") quantum computer by the end of this year. This computer will use qubits made of superconducting circuits. Each qubit is prepared in a precise quantum state based on a two-state system. The test will be a milestone in quantum computer technology. In a subsequent presentation, Sergio Boixo, Martinis' colleague at Google, said that a quantum computer with approximately 50 qubits will be capable of certain tasks beyond anything the fastest classical computers can do.

Researchers say that quantum computers promise an exponential increase in speed for a subset of computational chores like prime number factorization or exact simulations of organic molecules. This is because of entanglement: If you prepare entangled qubits, you will be able to manipulate multiple states simultaneously.

To demonstrate that their 49-qubit quantum computer works, Martinis's group will first precisely prepare the qubits—embedded on a chip—in an initial quantum state. Then, they will control the qubits using applied potentials and let the states evolve. Finally, they will measure the qubits' state and compare it to a theoretical simulation of the experiment calculated by a classical supercomputer. If the final state matches their classical simulation, they will have successfully controlled the evolution of the qubits—which means they can perform quantum computations.

This particular demonstration won't correspond to a useful computational task. It's just to show they have control over their qubits. "It's not a useful algorithm because it's a random algorithm," Martinis says. "But we can still take the output of that and compare it very precisely with a computer simulation to make sure it matches properly."

They need to work out the details, but Martinis says they already have the big picture design for the 49-qubit computer. "We actually feel pretty comfortable about everything," Martinis says. This is because his group has already successfully built and tested a 9-qubit version.

Before making the 49-qubit version, they will first scale up to a 20 or 30-qubit computer. Doubling the size of a quantum computer is like making a dual-core computer when you already know how to make a single core one, Martinis says. "Of course there are interactions that you have to worry about, but once you know how to make one, it's not hard to make two and put them together," he says.

The usual experimental hangups apply, too. "We'll have 120 wires coming to our qubit chip, and they all have to work," Martinis says. "Of course something is going to go wrong, and something will break." It will also be challenging to control the noise: more qubits means more room for errors.

At 49 qubits, this quantum computer will still be far from broadly useful. To make a "universal" quantum computer—something that might supplant your office computer—"you need millions of qubits," Martinis says.

Furthermore, a universal quantum computer will need to be able to correct its errors, which result from imperfect qubit preparation or

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IOT continued from page 1

which parts of a field receive water—as opposed to watering the whole field at once. Using this approach, IBM helped the California winemaker Gallo reduce water consumption in a test vineyard by 25%.

While many IoT applications could use existing sensors, others will require more specialized technology. David Chow, who oversees microelectronics at HRL Laboratories in Malibu, described radio-frequency circuits made from graphene embedded in a sheet of microbial cellulose, a biocompatible and flexible material produced by bacteria. Such circuits are elastic enough to be integrated with tissue in the body and might one day be used to stimulate a prosthetic limb via remote control.

But sensors alone aren't enough: You need a "brain" to process and interpret the colossal amounts of data that the IoT generates, and a number of presentations at the meeting highlighted advances in artificial intelligence and machine learning that are making this possible.

This is where quantum computing might eventually play a role, suggested physicist Seth Lloyd of MIT. "Many of the things we're doing with classical machine learning could get an exponential speed-up with a quantum computer," he said. That's because quantum computers are whizzes at linear algebra, the mathematics used in search and optimization algorithms.

Of course something has to power all of this sensing and processing, which is creating a demand for new types of batteries. Andy Keates, an engineer at Intel in Santa Clara, explained that while there are many battery options, it may be difficult to find one that is both compact and satisfies the many requirements for IoT devices.

"Honestly, no one is ever fully satisfied with their batteries," he said.

Speakers at the meeting didn't shy away from voicing the potential downsides of the IoT. A big concern is security. Last October, for example, hackers harnessed video cameras and other unprotected devices on the internet to orchestrate a denial-of-service attack that took down major sites such as Netflix and Twitter.

Nancy Cam-Winget, an engineer at Cisco specializing in IoT security, presented this vulnerability issue as a challenge to physicists, who will need to design devices for the IoT with enough room for self-protection hardware, but at a cost that companies are willing to swallow.

There's also the natural aversion to having machines take over our lives. Self-driving cars sound great—until you're in one and it makes a mistake.

"We don't have a high tolerance [for accidents] when machines are involved," said Allen Adler, who leads technology strategy for Boeing.

And if you find this hooked-up world of spying objects disturbing, you aren't alone. Jeffrey Hunt, a physicist at Boeing in Los Angeles who chairs FIAP and co-organized the meeting, says that when he first heard about the IoT, "I went home ready to cut my cables and wear a tin hat."

Lloyd confessed that he also finds the idea of being watched by so many devices "creepy."

Barbara Jones, a physicist at IBM in Almaden and former FIAP chair who organized the meeting with Hunt, advocated for educating the public to prevent unnecessary fear. The IoT should be an "easy sell", she said, both because it's useful to industry and because it sounds cool.

She said the challenge will come if sensors aren't just used for obvious benefits, and are increasingly found "in cities, in suburbs, in schools."

And while Hunt says he'll continue to cover the camera on his laptop, he also believes the IoT is an opportunity that shouldn't be missed.

The author is Editor of Physics *(physics.aps.org)*

Careers Report

Physicists Make a Splash at Innovation and Entrepreneurship Conference

By Crystal Bailey, APS Careers Program Manager

In Washington, DC on March 24-25, VentureWell (venturewell.org) held its annual *Open* conference, which focused on teaching innovation and entrepreneurship (I&E) in STEM fields. The two-day event included sessions and workshops focusing on promoting entrepreneurship on campus (e.g., how to unite a large university around entrepreneurship and "bust the silos"), incorporating industry partnerships into programs, teaching entrepreneurial mindset, innovating in campus makerspaces, and increasing participation and success of underrepresented innovators. VentureWell is a non-profit organization whose mission is to cultivate and foster collaborations among students, faculty, and researchers to provide opportunities to realize their potential to improve the world.

Though this conference routinely attracts educators from various STEM fields (e.g., engineering and chemistry), as well as a sizable number from non-STEM fields (e.g., business and art), this was the first year where a sizable contingent of physics educators was in attendance. Among these were collaborators in the APS PIPELINE project, funded by a three-year grant from the National Science Foundation and aimed at developing and disseminating approaches to teaching physics innovation and entrepreneurship (PIE).

The conference provided a unique opportunity for physics educators to learn best practices and network with a broader community of innovation and entrepreneurship education practitioners. At a dedicated physics session, four physicists, including PIPELINE members, presented posters on the PIE projects underway at their institutions. I spoke on building interest in innovation and entrepreneurship within the physics community. Doug Arion of the Carthage College *Scienceworks* program described the findings of the J-TUPP report, a recent publication from the Joint Task Force on Undergraduate Physics Programs (1) that helped show how the undergraduate physics curriculum can be revised to better prepare students for a diverse set of careers. Many of the PIE implementation practices under development by the PIPELINE team and others align with the recommendations of this report.

There was also a workshop on Sunday specifically focused on PIE that was attended by about 15 physics faculty. The group discussed the main challenges to adopting PIE practices on their campuses, and identified key strategies learned at the conference to overcome those challenges. The challenges that were identified fell into four broad categories: having the time or resources to implement PIE activities, gaining high-level institutional support for doing PIE activities, learning enough about PIE to effectively teach it, and connecting with a broader community of PIE practitioners. Two of the strategies for overcoming these were including students in the design of PIE courses and creating a resource that documents all I&E activities taking place at a given institution to allow for more robust partnerships across campus.

PIE is important because the majority of physics students find employment outside of permanent faculty positions, yet there are very few experiences in the standard undergraduate program that explicitly help prepare students for these career eventualities.

Many graduates are destined for careers as entrepreneurs or *intra*-preneurs—scientists creating new products or processes in the context of an existing company—and could benefit greatly from having an insight into the basic values and principles that define success in those contexts.

Furthermore, most of the world's most game-changing technologies (e.g., the transistor, the laser, medical devices, and the fiber optic cable) have originated in the minds of physicists, who are able to draw upon a deep understanding of the physical world to create new, out-of-the-box solutions which in turn lead to new technologies. Widespread incorporation of technology-focused experiential learning spaces in physics departments will leverage students' versatility, curiosity, and creativity, and allow them to apply that deep knowledge to addressing important human needs.

As an organization that has been committed to supporting innovation and entrepreneurship education within the STEM fields for decades, VentureWell makes a great partner for this effort. Plans are underway to reach out to a larger cohort of VentureWell's membership affiliated with physics departments, and to continue to grow this community's presence at future *Open* conferences, such as the 2018 gathering in Austin, Texas.

To learn more about what's going on with physics innovation and entrepreneurship, visit the PIE website (go.aps.org/2qnDmTH) or sign up to receive a monthly PIE newsletter at (go.aps.org/2qnkaW8). Anyone interested in participating in physics events at the 2018 Open conference should email me at bailey@aps.org.

Note

1. The Joint Task Force on Undergraduate Programs is a project of the American Association of Physics Teachers and the American Physical Society: go.aps.org/2oFQFmj

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control. But error correction is not straightforward. A classical error-correction method involves duplicating data, but you can't duplicate a quantum state—a fundamental rule known as the no-cloning theorem. Researchers have proposed quantum error correction algorithms, but the Google computer won't use them yet.

Even so, researchers think that quantum computers of this scale will be capable of specific tasks, particularly for chemistry problems. Alán Aspuru-Guzik of Harvard University talked about using quantum computers for designing molecules for new materials. For example, Aspuru-Guzik wants to simulate organic photovoltaics for solar cells.

Currently, classical computers must make approximations to simulate quantum properties of molecules. But given their inherent quantum-ness, quantum computers should be able to simulate these properties exactly. Aspuru-Guzik has spent years figuring out how to translate these chemical simulations into a format that a quantum computer can read and manipulate.

The speakers also proposed ways to streamline the operation of near-term quantum computers. Krysta Svore of Microsoft talked about how quantum software should be structured for easy programming and compilation. Aspuru-Guzik discussed an algorithm for simulating model systems that combines the use of both a quantum and classical computer. "You want to harness each computer to do what they do they best," he says.

In other sessions, researchers presented experimental progress on qubits themselves—not just superconductor-based ones, but also semiconductor-based ones such as silicon quantum dots. Researchers from Rigetti Computing presented a way to place superconducting qubits on an integrated circuit that could be produced on chips on a large scale. A group led by Matteo Mariantoni from Canada's University of Waterloo presented a method to prevent errors in qubits: shield them with aluminum superconducting circuits coated in indium.

These shielding efforts reflect a fundamental challenge in engineering qubits. In order to hold information, a quantum computer needs to keep a qubit in its quantum state for a long time. "The best way to do that is to isolate the qubit from the rest of world," Martinis says. But then they can't interact to perform a computation.

Published last month in *Nature*, the Google group predicted that industry will commercialize small, specialized quantum computers five years from now. "If we can do something useful and commercially viable, then there will be funding to build up the industry and scale up," Martinis says.

The author, a contributor to Wired *and* Physics Girl*, is based in Tucson, Arizona.*

Education & Diversity Update

Graduate Education and Bridge Program Conference Materials Now Available

More than 150 faculty members, administrators, and students came to College Park, MD on February 10-12, 2017 for the third APS Graduate Education Conference, which was held jointly with the APS Bridge Program meeting. Participants heard talks and participated in workshops on topics including holistic admissions practices, program innovations, working with mental health issues, and best practices for recruiting and retaining a diverse graduate student cohort. Many presentations are now available on the conference website for those interested: go.aps.org/2qmtqtC/

2017 Physics Teacher Education Coalition Conference

Slides from the 2017 Physics Teacher Education Coalition (PhysTEC) Conference are now available at the PhysTEC website (phystec.org). The nation's largest meeting dedicated to educating physics teachers took place February 17-18 in Atlanta and featured workshops on best practices and presentations by national leaders in physics teacher education.

PhysTEC Teacher of the Year

Alexandra Boyd of Holly Springs High School in Holly Springs, North Carolina was named the 2017 National PhysTEC Teacher of the Year. This award recognizes outstanding high school physics teachers and demonstrates the impact of physics teacher preparation programs run by members of the Physics Teacher Education Coalition. Ms. Boyd, a graduate of PhysTEC member Elon University, was noted for her success as both a teacher and department chairperson in increasing AP Physics class enrollments in her school, especially in the numbers of young women taking physics. Learn more at phystec.org/toty/


Alexandra Boyd

Woman Physicist of the Month

Kiran Bhaganagar has made original contributions of applying the concepts of turbulence to study complex problems of wind turbines, atmospheric pollution, and chemical warfare agents. Currently, she is working on a novel way of integrating unmanned aerial vehicles in improving turbulence model predictions for atmospheric flows. As an associate professor and the chair of graduate student committee in the Department of Mechanical Engineering at the University of Texas, San Antonio, she teaches courses in numerical methods, fluid dynamics, turbulence, and computational fluid dynamics, and takes an active role in training and mentoring graduate and undergraduate students. Nominate the next Woman Physicist of the Month at www.womeninphysics.org!


Kiran Bhaganagar

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While Snow's scientific readers may have cheered him on, the reaction to his lecture was swift and harshly negative from the humanities corner. Famed literary critic F. R. Leavis derided Snow as being "intellectually as undistinguished as it is possible to be." His colleague, Lionel Trilling, was more circumspect, but expressed concern that Snow's tribal approach to two cultural camps further hampered "the possibility of rational discourse." (Decades later, biologist Stephen Jay Gould would write that Snow's basic argument was damaging and short-sighted.)

Snow published an updated version, *The Two Cultures: A Second Look*, in 1963, in which he softened his stance a bit. He acknowledged that a so-called "third culture" was emerging via the social sciences, which, like the arts, were primarily concerned with "how human beings are living or have lived." He died on July 1, 1980, in London, but his words in that 1959 lecture and book continue to resonate today. As recently as 2008, *The Times Literary Supplement* listed *The Two Cultures and the Scientific Revolution* as one of the top 100 most influential books since World War II.

Recommended Reading:

Jardine, L. 2010. "C.P. Snow's Two Cultures Revisited, *Christ's College magazine*, 48-57.

Snow, C. P. 1959. *The Two Cultures and the Scientific Revolution*. London: Cambridge University Press.

Snow, C. P. 1963. *The Two Cultures: A Second Look.* London: Cambridge University Press.

An Insider's Look at the Goldwater Scholarship

By Rachel Gaal

A Goldwater Scholar has a big reputation to uphold. Known by many postgraduate institutions as the "premier undergraduate scholarship" for research, students must apply through a campus representative, and must be nominated by their home institution to become eligible. Looking at the numbers, each scholar can receive up to $7,500 in funding for each of their junior and senior years. Applying to this prestigious and competitive award can be daunting, not to mention balancing the necessary coursework.

The Goldwater Scholarship is intended to fund undergraduates with the ability to eventually pursue and excel in research. Each applicant is encouraged to tell the story of their future goals, and explain their research intentions. While prior research experience is not an application requirement, a review of those selected for the award reveals that many, if not most students, are already involved in research. Virtually all Goldwater Scholars hope to pursue a Ph.D.

How does the scholarship benefit applicants beyond funding? And more importantly, what makes a student application stand out? In physics, it seems to involve a mix of time-management, making strong connections, and developing a passion for pursuing the unknown. Five of the 2017 physics scholars sat down with *APS News* and talked about their experiences of applying to the Goldwater scholarship.

Gabriel Juul is completing his junior year at Whitman College in physics. His research goals, however, involve aerospace engineering. When filling out his application, Juul found himself in new territory, writing about a field he had no research experience in—planetary science.

"[While] doing my research, I saw a planetary scientist discussing the terraforming of Mars in a YouTube video," Juul said. "I [decided to] reach out to him, and he put me in contact with a researcher who emailed me a list of extremely helpful sources."

Juul said that the application process in itself helped piece together his future goals. "I sometimes think I learned more during the weeks of my Goldwater application process than I did in an entire year studying at college," he admitted. "It forced me to bring down to earth some of the options that were floating around when I considered my future, to question how I might fit in a world of researchers, and where my research interests truly lie … These are questions I'm still answering, but the Goldwater process was immense in helping me grapple with them."

Étude O'Neel-Judy of Northern Arizona University used to despise math and physics. It wasn't until he started reading about general relativity and quantum mechanics in books by Stephen Hawking and Brian Green that he realized his calling was in physics research.

"The fantastic concepts presented in these works dazzled me more than any sci-fi," O'Neel-Judy explained. "My ambition to do research with general relativity drove me to ask [my professor] Dave Cole, what math that would require. With his guidance, and by asking around the department to find someone willing to teach me, within a year I had fulfilled all the prerequisites [for his general relativity course]. ... This was the [class] where I first had the idea that led to my research project."


Gabriel Juul


Étude O'Neel-Judy


Madelyn Leembruugen


Dylan Renaud


Evan Coleman

O'Neel-Judy is now working on an original project in mathematical physics—coming up with a way to model spacetime that is more visually intuitive. With the Goldwater Scholarship now in hand, he says his future plans have only become more research-focused.

"I haven't double-checked my math, but I believe that I will finally be able to quit my two jobs and devote all my spare time to research," stated O'Neel-Judy. "I plan on working on two simultaneous research projects next year, one in the math department, and one in the Gibbs Nanotechnology lab."

His advice to future applicants is to start as early as possible. "I wish I had started my freshmen year, but you can never do too much research," he said. "… Start developing good relationships with the faculty in your department, and with your research mentors. A good letter of recommendation from someone that knows you well goes very far."

Madelyn Leembruugen of the University of Cincinnati grew up knowing she wanted to be involved in research. But when her experience fell short of her expectations, she turned to outside resources for support.

"I began training with an observational astrophysics research group, but I realized I was not interested in computational research," Leembruugen said. "I [decided to] join the APS National Mentoring Community (NMC) and began meeting with a mentor, and participated in the Women in Science and Engineering (WISE) Research Experience for Women Undergraduates. During WISE, I began working on my current project under the supervision of my NMC mentor, Rohana Wijewardhana."

Leembruugen currently studies theoretical particles called axions, and their possible contribution to dark matter. While her research is mostly of the pencil and paper variety, not performed in a lab, her passion for pursuing theoretical research steered her goals for the future.

"Since winning [the scholarship] I have gained confidence in my own abilities, and become more determined to continue working hard," she said. "I think students considering applying to Goldwater should be bold and unafraid to discuss their triumphs, as well as the trials they face throughout their journey. I think it is also important for applicants to establish lofty goals whether or not they [are selected]. The best research is motivated by curiosity, not desire for recognition!"

Dylan Renaud of the New Jersey Institute of Technology was an honorable mention the first time he applied to the Goldwater scholarship his sophomore year. He had conducted research in Japan his freshman year, learning about spectroscopy and fabrication of 2D materials, but was not chosen as a scholar.

"The next year, I traveled to Germany after receiving a fellowship and pursued further work on [materials research]," Renaud said. "I also received help from [my professor] John Carpinelli during the nomination process. Without his support and guidance, I don't believe I would have received this award [my junior year]."

Not deterred by his first application, Renaud recommends applying for the scholarship despite any shortfalls that you think exist in your resume. "[Simply] apply to the scholarship! Technically, you don't even need to have research experience," he exclaimed. "Secondly, try to work with your

GOLDWATER continued on page 6

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1.3 T and the cells align themselves into the chains … in the lab, the viscosity along the flow [in the direction of the chains] is reduced over 25%, and perpendicular it almost doubles to over a 95% increase [over the original viscosity].”

This drastic change (brought about by a magnetic field over one million times stronger than Earth’s magnetic field) occurred over a mere four seconds — and the lower viscosity along the flow and increased oxygen function of the red blood cells, which lasted over 24 hours after treatment (1).

With these results, Tao and his team decided to modify their laboratory setup to perform preliminary clinical trials with volunteers who had high blood pressure. In the trials, the patient’s right arm is inserted along the axis of a powerful electromagnet, so the forearm, and the large artery in it, are parallel to the magnetic field.

“Our results were more wonderful than expected,” Tao explained as he showed an example of readings before and after treatment. Prior to treatment, one volunteer’s blood pressure read 140/99 mmHg. “Every minute we read his blood pressure, and after ten minutes, it went down to 115/75 mmHg.”

That’s equivalent to going from stage one hypertension to a normal range of blood pressure in under ten minutes. And the subjects’ blood pressure after eight hours was only slightly above normal.

“This patient for many, many years, has had high blood pressure, and now he says ‘I hope every morning I can come in for a treatment!’,” Tao said. “But 100%, every person [we tested] had their blood pressure down 10 to 20% within 5 to 10 minutes, and had increased oxygen function [in their blood cells].”

Tao has spent much of his research career tinkering with the applications of electrorheology (ER) and MR, in which electric and magnetic fields are used to change fluid flow. From transporting oil through pipelines to rewriting recipes for low-fat chocolate bars, his unconventional applications of ER and MR have produced innovative approaches to a variety of problems.

The blood pressure results caught the eye of the American Heart Association, which is now involved in helping Tao and his team receive formal approval from the FDA to conduct official clinical trials. Tao said he looks forward to one day having this type of therapy for at-risk people to lower their blood pressure without the use of prescribed medicine or invasive surgeries.

“At this point, this technology seems to be wonderful … [and] from a physics point of view, we solved the bigger problem.”

References

1. Tao, R. and Huang, K., Reducing blood viscosity with magnetic fields. *Phys. Rev. E* 84, 011905 (2011).

GOLDWATER continued from page 5

research supervisor when writing your research proposal for the scholarship. I ended up writing my proposal by myself, and this led to me having to do a substantial amount of literature review which interfered with [my] coursework.”

Evan Coleman of Brown University is the first physics major from Brown to receive a Goldwater Scholarship. His interest in particle physics led him to explore the mentoring available at Brown University early on in his undergraduate career.

“Our physics department has around 30 students per year,” Coleman said. “... [My advisor] Meenakshi Narain heard through one of his students that I was interested in research. I decided to reach out to him, and by the end of my first semester at Brown, I was working in particle physics. Through Professor Narain’s support, I spent that summer at Fermilab, where I contributed to various particle identification projects and quark property measurements. I’ve been hooked on particle physics ever since.”

Now with the application process behind him, Coleman says it has prepared him in the best way for graduate school. “I was forced to put my personal story into words, and to communicate my motivations within physics effectively,” he said. “I hold strong opinions on the purpose of physics, but I had not previously needed to write them down. … Receiving the Goldwater Scholarship has bolstered my graduate school motivations. I am honored that my work has been recognized.”

In honor of their achievement, APS offered a free one-year membership to the new Goldwater scholars. To learn more about the Goldwater Scholarship and their requirements, visit the Barry Goldwater Scholarship Homepage at go.aps.org/2oFR20b

PHYSTEC continued from page 1

“We always have to say ‘There is a critical shortage of physics teachers’ due to the fact that over half of high schools classes are not taught by someone with a physics degree’,” says Renee-Michelle Goertzen, APS education programs manager and PhysTEC principal investigator. “A lot of physicists don’t know this ... but it’s simply the case of why [our] program has to exist.”

PhysTEC was founded in 2001 with a mission to “improve and promote the education of physics teachers at the secondary school levels.” The program’s network of schools has grown to over 300 institutions spanning all 50 states, including seven international member institutions. While some are involved in partial programs, receiving smaller grants from PhysTEC, there are multiple schools that received awards which revamped their whole curriculum.

These schools, called Comprehensive Sites, go through a set of crash courses to weave the key components of successful physics teacher preparation into their undergraduate programs. By including specific components—such as teachers-in-residence, mentoring opportunities, and early teaching experiences—their new curriculum embodies a complete learning experience and serves as an “all-star example” for other schools to emulate.

The results of PhysTEC’s helping hand tells a story of significant improvement in the number of physics teachers headed into the classroom (see chart on page 1). In particular, out of the 21 Comprehensive Sites before funding, over half graduated zero teachers per year. After their grant period, the total number of physics teachers graduating from Comprehensive Sites tripled, with some schools graduating over seven teachers each year on average. If all U.S. physics departments did the same, the national physics teacher shortage would be nearly eliminated.

For those schools that graduate five or more students per year, the institution is inducted into the PhysTEC 5+ Club. Every year, this special initiative continues to grow—and this past academic year, nine new U.S. institutions were inducted.

Schools that are currently or were previously involved in the Comprehensive Site grants were eager to share the difference it made to their school’s reputation and the overall interest in their physics programs. Georgia State University was one of the programs that hit the ground running when PhysTEC came along.

“We had a physics teaching preparation program, but only at the masters level,” Brian Thoms of Georgia State University told *APS News*. “One year before our grant, we started the undergraduate path [for physics teaching] in 2012.”

Thoms is the PhysTEC site leader at his institution and just finished his grant period in July 2016. Their once-new pathway offered a concentration in education within the physics bachelor degree, also leading to teacher certification.

“PhysTEC helped us get the new path going, and reform some of our courses to be more attractive and effective for the undergrads,” Thoms explained. “We also had a teacher-in-residence, an actual physics teacher who was in contact with the students … someone who could tell them what it’s really like in a high school classroom… [Our] grant helped to get the word out very quickly and to ramp up the undergraduate path from zero [students] to three or four students a year, right away.”

The popularity of the Georgia State undergraduate path landed them a spot in the 5+ Club this past year, their second award since 2013 when they graduated six teachers during their second year offering the teaching path. “Actually, this year and the year after, we are on track to get [The 5+ Club award] again,” mentioned Thoms.

Another school that has been apart of The 5+ Club in recent years, Middle Tennessee State University, had revamped its efforts for their undergraduate program in light of the state’s new requirement that increased the number of science and math courses needed to graduate from high school. Physics professor Ron Henderson commented on the biggest benefits he’s seen at his school since getting involved with PhysTEC.

“One of the largest impacts was having a marketing consultant visit the department,” Henderson explained. “Us realizing how to phrase our message so it meant something to incoming students—that was a big deal.”

In addition to reforming their calculus-based physics sequence for incoming freshman, and rearranging the curriculum to offer a “physics teaching” concentration within the degree, Henderson said the site visits were among the larger impressions made on the University as a whole.

“These outside people coming here and saying, ‘This physics department is ready to do good things and educate high school teachers’... Even to this day, it has been years since [the site visits], but my president will [tell me], ‘That is so impressive that the representatives of [PhysTEC] came on site and were so complimentary of our department’.”

University of Colorado at Boulder has been involved with PhysTEC since 2004, during its first steps in supporting the Colorado Learning Assistant program that is renowned today. Noah Finkelstein, a professor of physics at Boulder, is one of the three site leaders for PhysTEC, and has seen an incredible amount of change in the way his department approaches the idea of teaching, regardless of career choice.

“Historically, we’ve beaten the interest out of people in freshman physics ... and our department wasn't active in negating that sentiment … PhysTEC and the learning assistant program helped us get the message out—that one of the best things you can do for your career is be an educator, and that it [can offer] a meaningful and rewarding life … All of this has shifted the overall mindset in our department, [and] we now have a staple class for both graduate and undergraduates for teaching and learning physics.”

No matter how many schools are activists for this cause, the PhysTEC family has their eyes on the prize—to encourage, recruit, and put qualified teachers into schools around the nation—to give the future physicists an exciting and rewarding look at physics in the classroom. To learn more about PhysTEC, visit their homepage at www.phystec.org.

More Photos of the March for Science


(L-R) The 2017 APS Presidential Line at the march in Phoenix, AZ: Vice President David Gross, President Laura Greene, President-Elect Roger Falcone, Past President Homer Neal; Three brothers and their signs. "I want to be a paleontologist!", one exclaimed. "Yeah, I want to be a paleontologist too, I like dinosaurs," said another. "[My husband and I], we aren't in science," the mother explained. "We are just here to support [our boys] and remind them that without them here supporting science, they might not be able to work their dream jobs"; Jim Kakalios spoke at the March for Science Teach-In tent; 2017 Optical Society of America President Eric Mazur with Jim Kakalios and APS Head of Outreach Becky Thompson looking at slides from Kakalios' talk.

Corrections

The article "How African-American Women Succeed in Physics" (April 2017) said that the Catholic Church excommunicated Galileo. In fact, Galileo was condemned by the Inquistion and put under house arrest but he was not excommunicated.

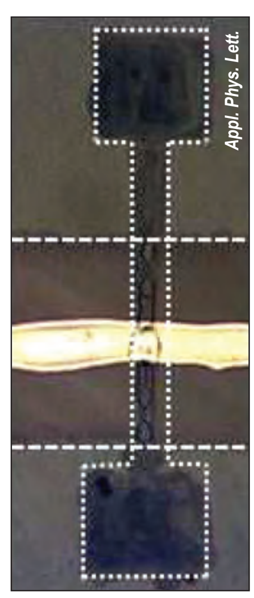
Owing to a production error, on page 5 of the same article, the photograph should have carried the caption "Desiré Whitmore."

RESEARCH continued from page 1

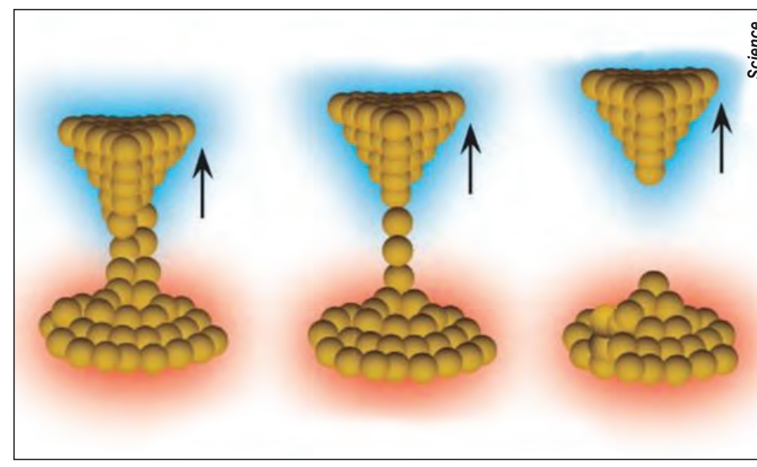
ejections, and large tidal effects, which can influence seasonality and geologic activity of the star. This Venusian look-alike is now on the research docket, to understand how it differs from Earth-like planets and what conditions might lead to habitability on a planet.

Thanks for the Printed Memories

While the microcircuit industry is largely based on multibillion dollar fabrication plants, one research group has gone to the other extreme—demonstrating a production scheme using an off-the-shelf inkjet printer. In a paper in *Applied Physics Letters* (DOI: 10.1063/1.4978664), Huber et al. report a scheme that can print memory devices onto flexible substrates. The memory cells are based on the recently developed ReRAMS (Resistive switching RAMs), which are based on resistance changes in a dielectric material. Each cell is made of an active layer sandwiched between two electrodes. The active region was printed with a polymer that when sintered formed a silicon oxide layer. One electrode was printed with silver nanoparticle ink and the other was a conducting polymer. When a current is sent through the oxide, a tiny metallic filament forms to create a low-resistance state (a "0"); reversing the current causes the filament to dissolve, creating a high-resistance state (a "1"). Previous attempts at printing such memory cells required costly post-printing fabrication steps, whereas Huber et al. could make the entire memory device with just a standard inkjet printer. The result may offer an inexpensive and robust way to make devices that don't require a constant voltage supply to retain their memory.



Researchers used an inkjet printer to fabricate a resistive memory cell.



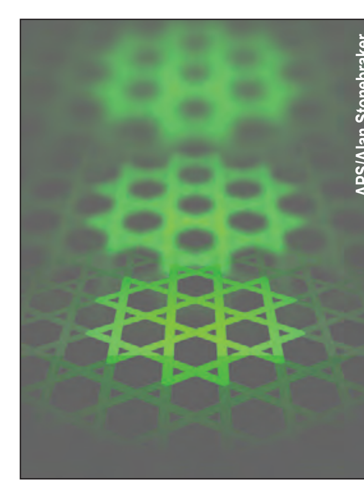
A cold gold probe in contact with a hot gold surface forms a metal bridge. Pulling the probe away narrows the bridge to a single atom junction for studies of thermal conductivity at the microscopic level.

Calorimetry "Conducts" an Atomic-Scale Experiment

A metal that can electrocute you when charged is also likely to become painful to touch when heated. This elementary relationship between electrical and thermal conductivity is one of the basic traits of a metal and is a demonstration of physics at the macroscopic level. At the atomic scale, the way heat is transferred through single-atom junctions has been experimentally inaccessible, with no way to measure the miniscule heat currents. Chi et al. report in *Science* (DOI: 10.1126/science.aam6622) a new way to measure thermal transport through gold (Au) at the atomic scale, using a custom-built calorimetry probe. The Au-coated tip of the probe (about 50 micrometers in size) was placed over a warmer Au substrate, and the two formed an Au-Au contact when a small electrical current was run through the probe. When the probe was withdrawn from this initial position, the metal particles slowly formed single-atom junctions, and their transport properties were recorded before the contact was broken. The experiment showed that the thermal conductivity was limited to a single range of values (or quantized values), which confirmed the basic relationship between thermal and electrical currents that holds true at larger length scales. And it inspired the development of a new device to be used in future molecular-scale studies.

Kagome Magnet May Be a Gapless Spin Liquid

Antiferromagnets with a triangular structure known as the kagome lattice can be gapless spin liquids in their ground state, numerical studies now suggest. The interest in spin liquids—systems of spins that, instead of ordering ferromagnetically, remain in a disordered state—stems from the fact that they could be useful for topological quantum computers. Kagome lattices are expected to be spin liquids, but calculating their ground-state spin configurations poses a formidable theoretical challenge. Conventional methods tackle the problem by computing the largest system one can simulate on today's computers and extrapolating the results to an infinite lattice, which best represents a real material with many electrons. But with available computing power, the lattices that can be simulated are too small to give reliable results. Now, Liao et al. have developed a new approach that finds the solution by optimizing a wave function that directly represents the infinite case. The results, reported in *Physical Review Letters* (DOI: 10.1103/PhysRevLett.118.137202) indicate that the ground state of the material is not only a spin liquid, but also gapless, that is, it has no energy gap between its occupied and unoccupied spin states. The tools developed through this work will help researchers describe this elusive state of matter and settle important questions about its electronic properties. (For more, see the Viewpoint in *Physics*, "Closing in on the Kagome Magnet" by Bryan Clark.)



The kagome lattice

The Back Page

What is the Evidence?

By Rush Holt

Note: This is a partial transcript of a presentation to the 2017 APS April Meeting in Washington DC, at which the author received the APS Joseph A. Burton Forum Award "*For outstanding contributions as Member of Congress and CEO of the AAAS in utilizing scientific evidence to inform our government and public on important national and international issues and working to implement policies and legislation that advance our national interest and strengthen the U.S. scientific enterprise.*"

Thank you for the Burton Award. I've been a member of the forum since 1975; I knew Joe Burton and really liked and admired him. He also gave me my stipend check each month when I was an APS Congressional Fellow.

I am honored and truly humbled, and I wish I belonged on the list with the previous winners of the Burton Forum award: Dick Scribner and Joel Primack, who were central to founding the Congressional Fellows Program of the APS and AAAS; Frank von Hippel, with whom I still collaborate all the time on international science issues and arms control; Ted Taylor, who went from designing very reliable and usable nuclear weapons, to devoting his career to making sure they were not usable or used and were regarded as obsolete; Philip Morrison, Martin Gardiner, and Victor Weisskopf, who educated many of us directly or indirectly; Steve Fetter, John Holdren, and Ernie Moniz, with whom I had been working up until just last week; Freeman Dyson, a truly admirable iconoclast, and a delightful person to bounce ideas off of; Lizbeth Gronlund, who has done so much for arms control; Bill Colglazier, who actually works for me now at AAAS after a distinguished career.

"... I've spent my time trying, not to communicate with the public to help them understand, but rather to understand the public ..."

However, I did want to mention two of the former awardees and call them out because they have been central to my public career in science. The first is Mike Casper, who was my teacher in quantum mechanics at Carleton College. He taught me not only a great deal of physics, but that a physicist can and should be involved in public issues. At Cornell, he had worked with Hans Bethe on the antiballistic missile movement and he showed that it was not only respectable for a scientist to be engaged in public activities, but really obligatory.

The other is Jeremy Stone, son of the famous journalist I. F. Stone. Jerry was a mathematician who devoted his entire life to bringing about peace. He died just a couple of weeks ago. He was for many years the head of the Federation of American Scientists. He was very influential for me, and was one of the people, when I said maybe I would run for congress, he said "you must." And he worked hard to build support and raise money for me to do it. So to be in the company of all of these Forum Award winners is truly an honor.

The Forum Award is to recognize work in public understanding of science and for resolution of public issues. For most of my career I've been involved, along with my physics research and teaching, in trying to help the public understand how science, and physics in particular, illuminate the public issues.

I must say that in the last year, though, I've spent my time trying, not to communicate with the public to help them understand, but rather to understand the public.

This has been a truly puzzling year or year and a half politically, and I must say, right now, I have never seen the scientific community so uncertain, so concerned, and so anxious. At any governmental transition, there are questions about what's going to happen with science funding, and what's going to happen with space policy, and health policy, and other things that affect our work.

But, this is almost a different order of magnitude. I find

that people, scientists, are wondering—does anybody get it at all, about the point of science? About this ingenious way of understanding the world, or as biologist Lewis Thomas said, this shrewdest maneuver for answering questions with evidence that is validated and verified.

Politicians from time immemorial have discarded inconvenient evidence and policy makers have always struggled to find a mechanism for policy making that allows scientific evidence to be central to the process.

Now, scientific evidence is rarely the primary ingredient in political sausage-making. Ideally it is the primary ingredient in policy making, but that is never easy. Scientific evidence can never or at least rarely be the sole input for policy making.

But we scientists believe that evidence is special. We have, I would argue, a reverence for evidence.

Let me just stop for a moment, and distinguish politics from policy. Politics is the balancing of competing interests. Too often, particularly if they're thinking about getting involved in politics, scientists think that politics is dirty. Well, it can be dirty, but no more than any other walk of life.

Policy making is the attempt to solve or avoid public problems by guiding human actions and using human resources, and policy makers struggle to come up with a system that can make evidence primary in that policy making.

"... We find ourselves at a time when evidence ... is willfully denounced and banished in principle ..."

Well, now we find ourselves at a time where evidence isn't just introduced in policy making in a mistaken way, or in an unevaluated way. But it is willfully denounced and banished in principle, whether it's about gag orders at the Environmental Protection Agency or any of number of the other restrictions on scientific activity.

I think what is most troubling to us, and as I read it, to the science community at large, is that a unnerving trend that has gone on for some decades now, that I call an erosion for the appreciation of science. And it has reached a point where almost everybody realizes—this really makes a difference.

If you can have this fact, or this alternative fact, and they're equivalent, that calls into question the very idea that science is a special way for separating truth from falsehood, a special way of answering questions with evidence that can be verified.

I just want to make one point for you. It's based on the premise that you should be involved in public questions to some extent. I'm not saying everyone should run for office. But I start with that premise and then try to get to the question of, well, how.

Scientists, by virtue of our special training, do have this special obligation to be involved in public engagement, in politics, perhaps in an advisory role, or in policy making, if only at the local level.

It is a frustrating time now, a discouraging time, a disheartening time, but we should not give up trying, and I think in doing this work, we have to shift from what has been our traditional role as experts as people who understand how the physical world works.

We should shift from trying to communicate the right answer, to communicating the right process.

"We should shift from trying to communicate the right answer, to communicating the right process."

It is easier to say, to the policy maker, to the public, here's what the science says, here is the answer, here is my direction to you. Now, that can be off-putting certainly. There are all sorts of reasons we probably shouldn't have done that over the years, but right now more than ever we must avoid that.

The whole problem is a loss of appreciation for science, not a mistaken understanding of the facts on a particular issue, but a rejection of the idea that evidence, vetted scientifically, is better than ideological assertion and opinion.

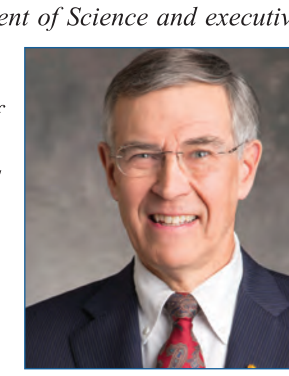
For some years I've been talking about this erosion in the appreciation of science, and people would nod and say, "Yeah I think I see that, maybe." But now, where fake news is indistinguishable in many people's minds from fact, we have to act.

It will not be done by *asserting* what the facts are, but rather empowering people to handle evidence for themselves, to rebuild the traditional American reverence for evidence, and the scientist's reverence for evidence. And let them know that, whatever their level of expertise, they can demand evidence and make some judgments about its value—on any particular piece of evidence.

They may say, "Well I'm not an expert in dealing with these complicated issues." Each of you [in the audience today] can make judgments about evidence in scientific fields that are not your own, by asking what is the evidence and making some judgments about the validity of what you hear.

We have to let people know that it is not our job to do that for them. It is their job to do it for themselves, and they can.

We have to help them understand that science is not just for scientists. That, at their level of expertise, they can deal with it. At their level of expertise, whatever it is, their first question can be and should be "What's the evidence?"



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