APS News

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What the James Webb Space Telescope Can Teach Scientists About Engaging the Public

At the APS Annual Leadership Meeting in January, Matt Mountain, AURA President and JWST scientist, shared his lessons on how to pull the public into science.

BY LIZ BOATMAN

Playwright George Bernard Shaw once said, "The single biggest problem with communication is the illusion that it has taken place."

For Charles Mattias Mountain, president of the Association of Universities for Research in Astronomy (AURA) and scientist for NASA's James Webb Space Telescope (JWST), these are words to live by. During the APS Annual Leadership Meeting in late January in Washington, D.C., Mountain opened his talk by flashing Shaw's words on the screen.

Although AURA — a nonprofit consortium of U.S. and international institutions — is not part of NASA, the two groups are long-standing partners. AURA operates astronomical observatories for NASA, and the JWST's science team is housed in AURA's Space Telescope Science Institute in Baltimore. AURA staff also works to inform the public about the JWST.

The Tarantula Nebula, captured by Webb's Near-Infrared Camera (NIRCam). Credit: NASA, ESA, CSA, STScI, Webb ERO Production Team

Despite the JWST's fame today, its future wasn't always secure. In 2010, the mission's costs were spiraling out of control and construction was years behind schedule. An article in *Nature* dubbed the JWST "the telescope that ate astronomy," congressional leaders were scrutinizing the program's budget, and some wanted to cut funding.

For AURA, it was a moment of reckoning. "We realized we had to go back around and re-convince not just the public, but our own science community, that understanding the origins of the galaxies was actually important," Mountain said at the Annual Leadership Meeting. So AURA assembled a communications team

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This Summer, Particle Physicists Will Prioritize Projects for the Field's Future

The P5 panel is gathering information that will shape its recommendations.

BY DANIEL GARISTO

The future of particle physics in the U.S. hinges on what Hitoshi Murayama, a theoretical particle physicist at the University of California, Berkeley, and 30 other members of the Particle Physics Projects Prioritization Panel (P5) decide later this summer.

Last year, particle physicists conducted the Snowmass 2021 process (it was delayed until 2022 by the pandemic) and submitted over 500 white papers, each a vision of the future. Toward the end of the process — which is organized by the APS Division of Particles and Fields — they gathered in Seattle for 10 days to hash out a consensus on which scientific questions should be pursued, and the experiments they'd like to pursue them with. As the curtain closed, Murayama was announced as the chair of P5, which, as its name suggests, is designed to prioritize projects — eventually.

Physicists flocked to Seattle last year to plan the future of U.S. particle physics. Credit: Ben Babusis

"We are not ready to discuss prioritization yet, because we haven't understood the cost and schedule for each project," Murayama says.

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Get Ready for the APS April Meeting 2023

In Minneapolis or online, physicists can connect over the latest discoveries, "from quarks to cosmos."

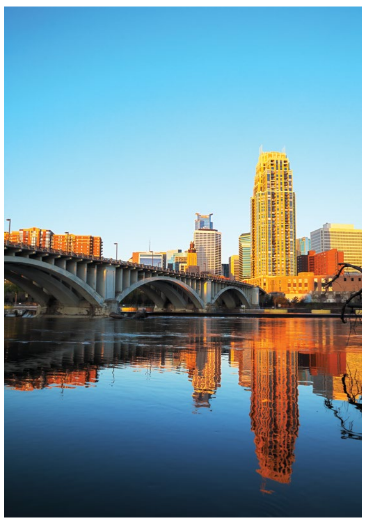
BY LIZ BOATMAN

Remember that old saying, "April showers bring May flowers"? After this year's long, cold winter, Minnesotans will be lucky to see flowers in May — but in Minneapolis, folks are guaranteed to see physicists this April. Lots of them.

The APS April Meeting 2023 will bring physicists from across the country and around the world to Minneapolis from April 15-18 for an in-person extravaganza of scientific talks on topics ranging from nuclear physics to astrophysics — that is, from quarks to cosmos. Others will opt to join the virtual meeting, scheduled April 24-26. All attendees are welcome to participate in both.

"We have a fantastic slate of parallel and plenary sessions," says Abhay Deshpande, chair of April Meeting 2023 and professor of physics and astronomy at Stony Brook University in New York.

Deshpande recalls his first April Meeting, in 2002: He says that he was "overwhelmed by the diversity and expertise in physics" showcased



Minneapolis, where the in-person APS April Meeting 2023 will be held.

that year in Albuquerque, New Mexico, but that it also motivated him to pursue a career in physics. He hopes this year's meeting will arouse that same excitement in more early career scientists.

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To Manage Future Risks of Emerging Technologies, Train Physicists in Ethical Decision-Making Now

Panelists and audience members at the APS Annual Leadership Meeting made the case for adding lessons on ethics in technology to physics programs.

BY LIZ BOATMAN

Can a technology be inherently good or bad, or are the ethics of a technology determined by who uses it, and for what? Perhaps more importantly, who determines the answers to these questions, and what role should a technology's inventors play in this process?

In late January, during the Ethics and Emerging Technologies panel at the APS Annual Leadership Meeting in Washington, D.C., panelists and audience members explored these questions.

Emerging technologies — for example, artificial intelligence or quantum computing today — drive economies. That's one reason why nations around the world, including the U.S., invest in basic and applied research. But new technologies also bring risk, and not all that risk can be foreseen, even by the best-trained and most experienced scientists.

"Even if [scientists] know a lot about a field on the technical side, they're not always the best at trying to predict what the future might entail," said panelist William Colglazier, of the American Association for the Advancement of Science.

Social media is a great example. "We totally underestimated what the impact of [its] disruptive effect could be," said Colglazier. "There really are such things as unexpected, unanticipated consequences. ... It has to do with our human limitations."

To complicate things, nations must balance open science and international collaboration with national security, Colglazier added.

Attendees in the audience at the APS Annual Leadership Meeting in Washington, D.C., in late January. Credit: APS

"In many ways, the incentive [in scientific research] is to move fast and break things, and sometimes you have to understand what you're breaking, what the implications of that destruction [are]," said Vaughan Turekian of the National Academies, who moderated the panel — a difficult but important task.

Of course, nobody can see the future, which means even the most careful attempts to predict the social, financial, or political risks associated with an emerging technology may prove inadequate or misguided. Even so, a new technology's inventors — the people who best understand the technical elements of that new technology — are at least obligated to try to envision these risks, some panelists suggested.

The panel gave nuclear fission as a historical example. Physicists working on the Manhattan Project knew the end goal was the deadliest weapon ever made. Some — like Edward Condon, Leo Szilard, and Harold Urey — joined conversations around the future regulation of the then-new technology. Their push for civilian input on regulation led to the formation of the think tank now known as the Federation of American Scientists. Those physicists didn't have all the answers, but they made sure science had a voice in the conversation.

The lesson might apply today. For example, perhaps programmers, many of whom are physicists, should play a similar role in debat-

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Controlling a Zombie Outbreak — and Beyond

A modified epidemiology model highlights the role of medical treatment in countering the spread of infections.

BY KENDRA REDMOND

How many doctors does it take to control a zombie outbreak?

Researchers from Los Alamos National Lab (LANL) and Babeş-Bolyai University in Romania have developed a model for investigating this surprisingly relevant question, which they published in *Physical Review E* on Feb. 9, 2023.

In most fictional stories of a zombie apocalypse, the reanimated corpses feed on humans. After a bite, humans become ravaging zombies looking for their next meal. With no medical or magical intervention, all people are eventually zombified.

Less the drama of plot twists and characters fighting for survival, the zombie apocalypse tells the story of an uncontrolled epidemic. And, like other diseases, its spread can be mathematically modeled. In terms of modeling, an epidemic is "a chain reaction on a set of interacting particles," explains Nicholas Hengartner, a senior scientist at LANL and coauthor of the new paper.

Researchers have applied epidemiology models to a zombie outbreak for more than a decade, and it doesn't look good. In this latest work, led by Cynthia Olson Reichhardt, also a senior scientist at LANL, researchers modified the susceptible-zombie (SZ) model — or, more generally, the susceptible-infected (SI) model of an epidemic. This model applies to lifelong infectious diseases for which there is no recovery. In an SI epidemic, the number of uninfected people always falls to zero over time. Victory for the zombies.

Typical SI models treat people like molecules in an ideal gas, bumping into each other randomly, explains Hengartner. "But there is some clustering in how we interact," he says. To capture this, the team treated people (and zombies) as active matter — as self-propelled, interacting particles that behave like birds in a flock or fish in a school — where clustering naturally emerges. The team also added a new category of susceptibles to the mix: Clerics (C). Clerics could heal infected people or reduce the rate of infection, but they could also be infected. The researchers call their model the susceptible-cleric-zombie-recovered (SCZR) model.

They ran the SCZR model for different infection rates, recovery rates, and numbers of clerics. Its predictions revealed two fundamentally different paths. When the number of clerics or recovery rate was low, the SCZR epidemic behaved like an SI epidemic and the zombies prevailed. But when the number of clerics or recovery rate was high, the clerics healed all the zombies to save humanity. The SCZR model allows you

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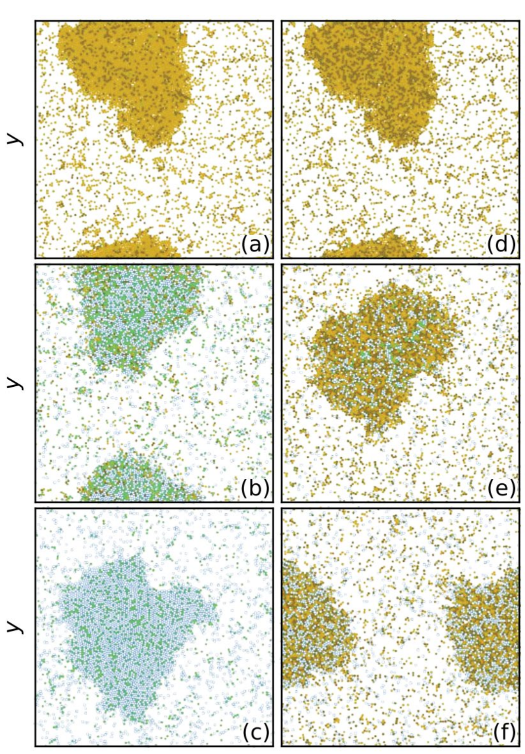

The susceptible-cleric-zombie-recovered model over time. Susceptibles are yellow, clerics are brown, zombies are green, and recovered are blue. (b) and (e) show the peak of the zombie outbreak. (c) and (f) show the final state. In (a), (b), and (c), all susceptibles and clerics are eliminated in the final state; in (d), (e), and (f), all zombies are eliminated in the final state. *Credit: Derived from A. Libál et al. / Phys. Rev. E 107, 024604 (2023)*

THIS MONTH IN PHYSICS HISTORY

April 1986: Bednorz and Müller Trigger Avalanche of High-Temperature Superconductivity Research

The duo's work energized the 1987 APS meeting that became known as the "Woodstock of Physics."

BY DANIEL GARISTO

J. Georg Bednorz (left) and K. Alexander Müller. *Credit: IBM Research Laboratory / Image Archive of the ETH Zürich Library.*

Nineteen months after J. Georg Bednorz and K. Alex Müller submitted their paper, "Possible high-Tc superconductivity in the Ba–La–Cu–O system," to the journal *Zeitschrift fur Physik B*, they received a call from Stockholm — the shortest time ever from a discovery to a Nobel Prize in Physics. The avalanche of research on high temperature (high-T_c) superconductivity they triggered started slowly. Though the paper was published in June, it received no citations for the rest of 1986. In 1987, the paper was cited over 1,000 times.

Normally, even the best electrical conductor resists some of the electric current passing through it, causing energy loss. But superconductors, discovered in 1911, have zero resistance, promising unparalleled efficiency.

Prior to Bednorz and Müller's discovery, however, superconductivity research had plateaued. Bardeen-Cooper-Schrieffer (BCS) theory, proposed in 1957, seemed to explain superconductivity adequately, and on the experimental side, the superconducting limit of 23.3 Kelvin (K) — around -249.9 °C or -417.7 °F — had not budged since 1973.

In the fall of 1983, Bednorz and Müller began searching for superconductivity outside traditional intermetallic compounds like niobium–tin. The idea to try metallic oxides came to Müller, as he recalled it, while "looking down on the ocean" (a great oxidizer) at a conference in Sicily. Research in the 1970s had already hinted at the potential of metal oxides like strontium titanate.

But Bednorz and Müller's first efforts with metallic oxides fell short. Lanthanum nickel oxide was unimpressive, and replacing the lanthanum ion with an yttrium ion didn't help. "We started wondering whether the target at which we were aiming really did exist," Bednorz later recalled in his Nobel lecture.

Rescue came when they got better equipment and switched from nickel to copper. In late 1985, Bednorz and Müller began working with lanthanum barium copper oxide (LBCO). "It was earlier discovered by Raveau," says Paul Chu, a high-T_c pioneer at the University of Houston. "But they only cooled it down to 77 Kelvin. I believe they were [some] of the most unhappy people on Earth at the time [of the Nobel]."

Finally, in February 1986, Bednorz and Müller observed a T_c of 35 K in LBCO. As Bednorz later told *The New York Times*, he celebrated with "one or two beers."

A modest celebration made sense, as high-T_c superconductors had been plagued by false alarms. To check their results, Bednorz and Müller imaged the crystal structure of their samples with x-ray diffraction and confirmed that the resistivity dropped sharply, but were unable to perform a key test: observation of the Meissner-Ochsenfeld effect, where a superconductor expels a magnetic field. Nevertheless, they submitted the paper on April 17 and — given the uncertainty — had to persuade a *Zeitschrift* editor to accept the article.

In September, new equipment arrived, and they were able to take magnetic measurements that added to evidence that LBCO was a bona-fide superconductor. Additionally, replacing lanthanum with strontium pushed the temperature to nearly 40 K.

A few groups were in hot pursuit to replicate Bednorz and Müller's results: Shoji Tanaka's group in Japan, Chu's group, and a group at Bell Labs. "Not too many people paid any attention to it," Chu says. "But when we saw it, we felt this is exactly what we're looking for."

"We started wondering whether the target at which we were aiming really did exist," Bednorz later recalled in his Nobel lecture.

Tanaka's group got there first in late November, corroborating Bednorz and Müller's results. In December, Chu and his colleagues confirmed LBCO was superconducting at 40 K — and could go higher, with

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APS Members Advocate for Science on Capitol Hill

BY TAWANDA W. JOHNSON

Anwesha Saha (second from left) and her team representing Michigan and Minnesota on Capitol Hill during Congressional Visits Day.

For doctoral student Anwesha Saha, scientists have a moral responsibility to share stories about their research with the general public. "It's not enough to just sit in your lab and work on science," Saha said. "We need to let people know how science affects them."

Saha, who studies applied physics at the University of Michigan, was among 90 APS members who attended the 2023 APS Congressional Visits Day (CVD) on Capitol Hill in Washington, D.C., which took place in January as a part of the Society's Annual Leadership Meeting. In about 100 meetings with lawmakers and staffers, attendees advocated for the Society's science policy priorities.

Saha said she was motivated to participate in CVD — her first — after talking with professors at her university, who previously attended and had positive experiences. Many of APS's science policy priorities are personal for Saha. Her lab's federal funding has been inconsistent. And as an international student, Saha expressed her support for the Keep STEM Talent Act. If passed into law, the legislation would authorize international students pursuing advanced degrees to express "dual intent" and legally declare their plan to pursue STEM careers in the U.S. after graduation. The bill would also exempt students — specifically, international ones who earn advanced STEM degrees from U.S. institutions and receive job offers from U.S. companies — from green card caps, which limit the number of employment-based immigrants.

"I am so glad that I had this opportunity to address my concerns with members of Congress," she said. "As an international student searching for internships, I often deal with 'Oh, you're not a citizen,' limiting my job opportunities."

"It's a tricky issue," she adds. "Many doors are closing, and I want to be able to stay in the U.S. to work."

Saha praised the APS Government Affairs team for preparing the CVD volunteers. "The one-pagers containing background information about the science policy priorities were concise," she said. "The training we received was also useful." She did her own extra research on members of Congress, too, including searching their voting records and committee assignments.

Saha also learned the importance of incorporating personal anecdotes during her CVD meetings. For example, while advocating for funding for the Robert F. Noyce Scholarship, a program that helps STEM majors become K-12 teachers, she pointed out how the program can help improve the diversity of STEM teachers.

"I brought up the fact that low-income people often struggle to pay back student loans and need scholarships to help them achieve their career goals," she said. "Data is important, but we should also make our stories personal."

Chris Fryer, director of the Center for Nonlinear Studies at Los Alamos National Laboratory, participated in his first CVD three years ago. He said the experience has taught him that it's important to connect science to larger issues impacting the country.

"There is a tendency of scientists to argue for science for science's sake, but I think we need to understand how science fits into the greater needs of the country," he said.

Both Saha and Fryer said they would recommend that APS members participate in future CVDs.

"You will come out of it with a better understanding of how our government runs," said Fryer. "I like to believe that I helped APS with its lobbying, but I think I gained much more in being a better advocate for science. I have a much better appreciation of Congress."

Saha valued her CVD experience, too. "If you can effect change, you should do it," she said. "It felt really good to do my small part."

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

Recipients of APS Innovation Fund for 2022

Two teams received Innovation Fund grants for 2022. First row: Diana Sachmpazidi (PI) and Chandra Turpen of the University of Maryland. Second row: Jacquelyn Chini (PI), Camille Coffie, and L. Trenton Marsh of the University of Central Florida.

Since 2019, the APS Innovation Fund has provided grants for projects that serve the physics community. Late last year, APS announced two teams that received grants for 2022, both for projects that aim to make physics more inclusive.

At the University of Central Florida, Jacquelyn J. Chini, Camille A. Coffie, and L. Trenton S. Marsh will collect the experiences of Black women in physics doctoral programs. The team will use these perspectives to identify promising best practices for more supportive, inclusive programs.

At the University of Maryland, Diana Sachmpazidi and Chandra Turpen will develop a survey to assess physics departments' readiness for inclusive cultural change. The duo will work with APS to identify focus areas for the survey, which the American Institute of Physics will administer and analyze.

After this cycle, APS will pause the Innovation Fund so that an independent committee can review it and develop recommendations for its future.

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ing the ultimate uses of artificial intelligence.

But ethics training is mostly absent from the education that most physicists receive in the U.S., noted one audience member.

"As physicists, I think we're trained to think that we know how to do everything," said APS President Robert Rosner, one of the panelists. "But sometimes we don't."

Of course, ethical dilemmas around emerging technologies aren't unique to physics, and other fields have tried to respond. For example, every undergraduate engineering program in the United States teaches ethical decision-making. This is a requirement of ABET, the nonprofit that accredits all undergraduate U.S. engineering programs. Without that accreditation, an engineering bachelor's degree in the U.S. carries almost no professional weight. Ethics training has also been increasingly incorporated into the biological sciences.

So why not physics? "Our physics graduates are going to be faced with many questions that are ethical," suggested an audience member.

While evaluating the ethicality of an emerging technology is a challenge that exists in "the gray," Rosner's stance on ethics training was more certain. "I would be a supporter of that," he replied to that audience member.

Data shows that roughly 1 in 5 undergraduate physics majors pursuing an advanced degree will do so in engineering, and more than 3 in 5 stay in physics or astronomy. Others leap directly into the workforce, often into engineering or research roles. And where do the rest go? Medicine, law, business, finance — all careers where training in ethical decision-making can help young professionals in a global economy and tech landscape, where the potential impact of an emerging technology is not limited by geopolitical borders.

> "In many ways, the incentive [in scientific research] is to move fast and break things, and sometimes you have to understand what you're breaking, what the implications of that destruction [are]," said Vaughan Turekian of the National Academies.

As an example, Rosner pointed to automated manufacturing, once an emerging technology. "It's one of the reasons we now have huge income gaps between folks that have gone to college and folks that have not gone to college. It's basically disenfranchised a whole generation of people," he said. "But other countries reacted differently … The vocational system responded to the changes in the talents that were needed."

"And that did not happen in the United States," he said.

So perhaps physics ought to look to programs in other STEM fields and strive for authentic engagement with ethics in undergraduate and graduate physics programs.

Panelist Julia Phillips, retired from Sandia National Laboratories, underscored this point when she asked, in the context of a discussion on artificial intelligence, "What does it mean to be human?" She added, "as physicists, we are ill-equipped to answer that question without engaging with a lot of areas of expertise and really deep contemplation" — like ethicists, historians, and other social scientists.

"If we don't grapple with those questions," she added, emerging technologies have the potential to easily lead us into "some really dark places."

Liz Boatman is a staff writer for APS News.

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to study how health care resources affect the outcome of such an outbreak, Hengartner explains.

Clerics are a fascinating addition to the SI model, says Stacey Smith?, a math and statistics professor at the University of Ottawa and coauthor of the first zombie apocalypse modeling paper, published in 2009 (the question mark is part of her name). Adding some clerics to deal with zombies one-on-one might seem like a small intervention, she says, but you can "pull the levers of how effective your clerics are" to swing from one outcome to another.

Whether clerics could actually heal zombies is up for debate; most universes don't allow the undead to come back to life. But that doesn't really matter to the researchers. The zombie scenario is an interesting way to encourage out-of-the-box thinking and raise awareness, Hengartner says. The team's underlying goal is to explore the impact of medical intervention on the infection rate of diseases like HIV and hepatitis C. In these cases, people who are untreated can infect others over a lifetime, but enough health care providers and resources can move the infection rate toward zero.

The researchers are currently expanding the SCZR model and working with collaborators to apply it to HIV data. If it's a good fit, Hengartner is optimistic that the model could help researchers, public health officials, policymakers, and others find answers to essential questions: How many doctors do we need to control an outbreak? How many treatment kits? And what kind of investment could change the outcome of this epidemic?

Kendra Redmond is a writer based in Minnesota.

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Currently, P5 is gathering more information, largely in the form of four town halls held at national laboratories: Lawrence Berkeley National Lab, Fermilab, Brookhaven National Lab, and SLAC National Accelerator Lab. Additionally, Murayama has added a subpanel under P5 specifically for cost assessment.

After aggregating all this information, P5 will deliver its preliminary recommendations in August, and a final report before Halloween. Nominally, the report goes to the High-Energy Physics Advisory Panel, but its ultimate destination is the Department of Energy, the National Science Foundation, and the legislative staff in Congress who control budgets. If the process is lengthy and a little byzantine, this is by design — planning experiments that can span decades and cost billions of dollars is complex work, even without the science.

ize in machine learning to accelerator physicists who build specialized machines. Five members of the panel are internationally based. This diversity of experience and expertise will lead to differing opinions, but Murayama hopes to reach consensus, instead of deciding with a numerical vote.

Part of the job involves translating this decision into a strong argument. "It's our responsibility to make the case why the science is important, why the science is exciting, and what our value is to society," Heeger says. While P5 is not organized to attempt to convince funding agencies in other countries, it has to remain cognizant of international factors because almost any sizable experiment requires multinational cooperation.

But perhaps the most important buy-in comes from within the community. "Any time you see a timeline

"Any time you see a timeline taking you out to 2070, people realize that we can't do this with one generation of a scientist," Gonski says.

Bureaucracy aside, particle physicists are excited. Karsten Heeger, an experimental neutrino physicist at Yale University, and co-chair of P5, says the first town hall had over 400 registered participants. "I'm very pleased by just seeing the engagement of the community, especially the young people," he says. P5 is planning additional virtual town halls to increase access for community members who can't be in person. This kind of accessibility is critical for early-career researchers who often lack the funds to travel, says Julia Gonski, a postdoctoral researcher at Columbia University.

At these town halls, whether in person or virtual, P5 is hoping to gain information that differs slightly from what was presented at Snowmass. "The Snowmass reports are basically about the aspirations of the community," Murayama says. "P5 is an exercise to put them together into a program that fits within a certain budget profile, so we need more information about the cost and schedule."

The DOE and NSF have already informed P5 that there are two main funding scenarios. "One of them looks really grim," Murayama says. In the first scenario, the budget for particle physics would increase by 2% every year — less than the rate of inflation. A brighter scenario includes initial funding from the CHIPS Act and a 3% increase year-over-year.

"It won't be possible to say yes to everything. That's just the reality," Heeger says. "But even if we have to de-emphasize certain aspects, there's still a ton of exciting science." In addition to monetary costs, particle physicists are also thinking about energy costs in light of climate change and the rise in European electricity prices, which cut short experiments at the Large Hadron Collider last year.

The trouble will be in the prioritization. P5 is composed of a broad swath of the particle physics community, from theorists who special-

taking you out to 2070, people realize that we can't do this with one generation of a scientist," Gonski says.

Heeger agrees. "One of the challenges in high energy physics is the timescale and the scale of experiments, and so we need to make sure that it also serves our younger colleagues," he says.

This Snowmass process was the first time that early career issues were treated as a "frontier" (like neutrino physics, or theory), with a report of their own. In addition to the increased involvement of early career researchers, Gonski also points to improved conversations about equity and inclusion. "Ten years ago, these were very novel concepts," she says. "We didn't have the diversity that we have now, in identity, in career stage, in socioeconomic [status]." The 2013 Snowmass survey found 79% of participants were male, and it did not even ask about race or ethnicity. The 2021 survey, by comparison, recorded 70% of participants as male and 68% as white.

The multigenerational aspect of Snowmass also means Gonski says she wants to learn things from those who have gone through it before her. "I really feel like we need to learn project management," she says. "Hitting those project milestones, from an organizational standpoint, is so important." Meenakshi Narain, a particle physicist at Brown University and P5 member, who died Jan. 1, was well-known as an expert in project management. "It was a big loss to the community and to the panel," Murayama says.

He and Heeger hope Narain's advocacy for early-career researchers — now memorialized in a mentorship award — lives on in Snowmass. "Young people are very engaged, they speak up [and] their voices are actually being heard," Heeger says. "Young people are also the ones that clearly have a stake in the future of some very exciting and challenging projects."

Daniel Garisto is a writer based in New York.

Congress Picks New Leaders for Key Science Committees

BY MITCH AMBROSE

The House of Representatives chamber. Credit: Office of the Speaker of the House

Following the 2022 election, which handed control of the House of Representatives to Republicans after four years of control by Democrats, Congress has made significant changes in the leadership of key committees that draft budgets and policy for science agencies.

While House Democrats have not changed the top members of appropriations subcommittees that write legislation that funds science agencies, House Republicans have reshuffled their leaders.

For instance, the House's Energy-Water Subcommittee, which has jurisdiction over the Department of Energy (DOE), is now chaired by Rep. Chuck Fleishmann (R-TN), a vocal supporter of national laboratories whose district includes DOE's Oak Ridge National Lab. The top Republican previously was Rep. Mike Simpson (R-ID), who is still a subcommittee member but now chairs a separate panel with jurisdiction over the U.S. Geological Survey and Environmental Protection Agency. Rep. Marcy Kaptur (D-OH) returns as the top Democrat on the subcommittee.

The Commerce-Justice-Science Subcommittee, which covers NASA, the National Science Foundation (NSF), and the National Institute of Standards and Technology (NIST), is now chaired by Rep. Hal Rogers (R-KY), the longest-serving member of the House. The top Republican in the prior Congress was Rep. Robert Aderholt (R-AL), who departed the role to lead a different panel but will retain a seat on the subcommittee. Rep. Matt Cartwright (D-PA) remains the top Democrat on the subcommittee.

Beyond the House appropriations committees, among the most significant leadership changes is that Rep. Frank Lucas (R-OK) is now chairing the House Science, Space, and Technology Committee, which oversees most civilian research agencies outside the biomedical sphere. Lucas has pledged to maintain the bipartisan character of the committee that existed under Rep. Eddie Bernice Johnson (D-TX), who chaired it from 2018 until she retired at the end of last year.

Lucas will oversee implementation of the CHIPS and Science Act, especially its $52 billion in subsidies for semiconductor manufacturing and R&D. He also plans to focus on competition with China, holding the committee's first hearing of the year on the topic.

"The Chinese Communist Party is determined to overtake us as the global leader in science and technology," Lucas remarked during the hearing's opening. "They're outspending us, out-publishing us, and out-educating us when it comes to STEM PhD graduates."

Lucas was one of the primary Republican authors of the science provisions of the CHIPS and Science Act, which proposes that Congress rapidly ramp up NSF, DOE, and NIST budgets. However, House Republican leaders have pledged to constrain federal spending overall, which could make it difficult for the appropriations subcommittees to meet the CHIPS Act's spending targets.

Rep. Zoe Lofgren (D-CA) has taken Johnson's spot on the committee and has identified fusion energy research as her top priority. Pointing to the recent breakthrough fusion experiment at DOE's National Ignition Facility, located near her district, Lofgren stated at the committee's first hearing, "I think a Manhattan Project level of commitment is needed now to ensure that the incredible promise of fusion energy is achieved."

On the Senate side, leadership changes on the Appropriations Committee were driven by the retirements of its top two members: Sens. Patrick Leahy (D-VT) and Richard Shelby (R-AL). The committee is now chaired by Sen. Patty Murray (D-WA); the top Republican is Sen. Susan Collins (R-ME). The Senate's Commerce-Justice Science Subcommittee will again be led by Sens. Jeanne Shaheen (D-NH) and Jerry Moran (R-KS), and its Energy-Water Subcommittee will again be led by Sens. Dianne Feinstein (D-CA) and John Kennedy (R-LA).

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.

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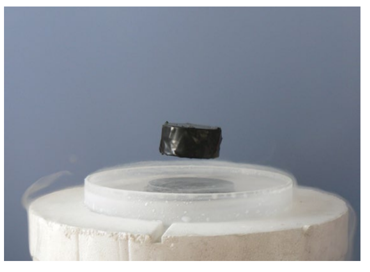
added pressure. They saw fluctuations as high as 100 K, but nothing stable until they swapped lanthanum for yttrium.

On Jan. 29, 1987, Chu's team synthesized yttrium barium copper oxide (YBCO). It superconducted at a balmy 92 K, warm enough that it could be cooled with just liquid nitrogen. "That really changed the world," Chu says.

When they submitted the paper to *Physical Review Letters* on Feb. 6, it was initially rejected. "What they did is have a square rectangle that the secretary put on top of your abstract," Chu explains. "If anything goes beyond that, it leads to automatic rejection." Theirs had been an eighth of a line too long. Scrambling, Chu called Neil Ashcroft, then chair of the Division of Condensed Matter Physics.

Excited by the news of YBCO, Ashcroft swung into action and within a few hours, organized the legendary high-T_c session of the 1987 APS March Meeting, which went down as the "Woodstock of Physics."

Videos and attendees' recollections testify to an electric atmosphere. Bars near the New York City Hilton where the meeting was held opened to physicists, and camera flashes lit the faces of presenters. Müller, Tanaka, and Chu introduced the groundbreaking work to applause and a rapt audience. Speculation abounded about possible applications and higher Tcs, as physicists debated whether there was a new mechanism of superconductivity at work, beyond BCS theory.



A magnet levitating above a high-temperature superconductor, cooled with liquid nitrogen — an example of the Meissner effect. Credit: Mai-Linh Doan

"Within a few months, the field of superconductivity had experienced a tremendous revival," Bednorz wrote in his Nobel lecture. "Nobody can predict where it will end."

The excitement spread beyond physics. Paul Grant, a condensed matter physicist, and his daughter Heidi wrote a "Shake 'n Bake" recipe for YBCO that could be synthesized in a pottery kiln:

- *Mix 1.13 grams yttrium oxide, 3.95 grams barium carbonate, 2.39 grams copper oxide*
- *Compact*
- *Grind in mortar and pestle*
- *Bake in air at 950 °C (1650 °F)*
- *Regrind in mortar and pestle*
- *Press into pellets*
- *Rebake pellets in flowing oxygen at 950 °C (1650 °F)*
- *Allow to cool very slowly*

By 1988, *The New York Times* reported that high school classrooms could buy a kit for $25 (about $63 today) with a superconducting pellet and magnet, cool it down with liquid nitrogen, and watch as the pellet of YBCO levitated above the magnet, thanks to the Meissner effect.

Earlier this year, on Jan. 9, Müller died at the age of 95. He never saw the revolution in technology many predicted during the heyday of high-T_c research. Instead, YBCO and other marvelous compounds proved unsuitable for commercial and industrial applications, and today remain mostly of interest to scientists — a reality Müller seemed at peace with.

"My best dreams are those where I am skiing downhill in good powder snow," he explained in a 2015 oral history. "Whenever I have this dream, I am convinced that I am totally okay with respect to my physical conditions, my attitude to life, and my knowledge."

Daniel Garisto is a writer based in New York.

Public Engagement continued from page 1

to rebrand the mission and persuade the government of the telescope's value.

It worked. On Dec. 25, 2021, the completed James Webb Space Telescope was launched into space aboard the European Space Agency's Ariane 5 rocket, from a launch pad in French Guiana. On July 12, 2022, its first images were released to the public. The telescope continues to make front pages across the world.

In just over 10 years, NASA not only rescued the telescope mission, but made "James Webb" a household name. "It was the result of a purposeful strategy," said Mountain.

During his talk at ALM, Mountain shared five lessons — gathered from years of outreach work for AURA — for other science organizations working to strengthen their public engagement.

Matt Mountain, speaking at the APS Annual Leadership Meeting in Washington, D.C., in late January. Credit: APS

1. Support "from the top" an outreach team with diverse staff.

Mountain recalled a time in 2009 when NASA's public affairs team was struggling to connect with the director's office during a campaign that required a series of last-minute maneuvers in space to transmit live footage of a Hubble deployment. As a result, the director's office didn't learn in time that the maneuvers could be done, and instead, the public learned about a quirky space shuttle device: the zero-g space toilet. "We missed that opportunity," said Mountain.

"We do things differently at AURA," he said. "We actually put the office of public outreach at the top level of the organization," so public outreach has "a seat at the management table when we're making decisions about the institution." And the public engagement team is diverse, too, comprised of scientists, science writers, educators, artists, and data gurus.

2. Use your active scientists.

Mountain said it's not enough to simply involve scientists in outreach efforts. The researchers you engage must be "your best" and "your most active" scientists.

He reminded the audience that many scientists aren't expert communicators. They typically require careful coaching to be effective at outreach, especially if they're playing highly public roles — for example, being interviewed by reporters or giving tours to members of Congress.

3. Be an expert, but don't lecture.

The American public is "hungry" for science, Mountain said — but too often, scientists revert to lecturing. To scientists, certain concepts seem fundamental; to an audience member, that "fundamental" concept might be lightyears beyond what they've learned.

As in a science classroom, it takes courage for a non-scientist to ask a scientist questions. In those moments, scientists must speak respectfully and ask their own follow-up questions to understand the non-scientist's perspective and knowledge level.

"Don't hide your expertise," said Mountain. "People want to talk to experts." But "don't talk down to them," either.

4. Realize that public engagement takes long-term investment.

Public engagement campaigns for research programs and long-lived infrastructure like the JWST are a long-term investment. That means they also require "a long-term commitment and a long-term strategy," said Mountain.

Some suggest allocating as much as 10-15% of your funding to public engagement efforts, he said. Remember, the JWST's success wasn't accidental — it stemmed from strategies "built over decades," he said. But funding isn't everything: For AURA's outreach team, "attitude and approach" to engaging the public are more impactful than simply having a lot of money or the NASA brand, Mountain said.

"And we measure everything," he added. Just like the science teams measure progress toward research goals, a public outreach unit should be measuring progress toward engagement goals. The most common metric used by their outreach team is "impressions," he said, which quantifies people's interactions with online content, like clicks.

5. Remember, "we don't do outreach for fun, but for funds."

"If we're going to do taxpayer[-funded] science … you have to show some return on the investment and actually engage with the public," said Mountain. "That's a duty you're bound by if you're going to take taxpayer [money]."

"Sometimes, we'll cut our engineering team or our science team to preserve our outreach team" when faced with a budget shortage, he added.

Mountain closed his talk by saying, "You need humility to keep reminding yourself that what you thought you did, didn't perhaps work quite as well as you'd hoped." That is, perhaps you didn't know your audience as well as you'd thought, or your outreach wasn't as polished as you'd intended.

"Go back around that loop again and again and again," he said, "until you've actually found something that works."

Liz Boatman is a staff writer for APS News.

April Meeting continued from page 1

April Meeting events in Minneapolis will kick off on April 14 with a public lecture on the physics of sport. During the scientific portion of the meeting, plenary talks will explore the impact of major facilities around the world on our understanding of physics, as well as the recent breakthrough in fusion technology and future steps toward introducing fusion-derived power into the U.S. power grid.

The meeting will also feature a range of events dedicated to enhancing diversity in physics. These events include the Kavli session on April 17, featuring Asmeret Berhe, director of the U.S. Department of Energy's Office of Science. Berhe will share her vision for a more inclusive U.S. science and technology workforce.

If you're headed to Minneapolis, note that the meeting will take place in the Hilton Minneapolis, which is also the meeting hotel. Many Minneapolis highlights are easily walkable from the conference venue. For art lovers, the Minneapolis Sculpture Garden sits next to the Walker Center modern art museum and Loring Park, several blocks to the west of the Hilton. To the east is the U.S. Bank Stadium, designed for the Vikings football team in the image of a Viking ship. To the north, city hall boasts a 365-foot-tall historical clock tower that once rivaled Big Ben. Farther north is the Mill Ruins Park area, home to the Guthrie Theater and Mill City Museum (where, in 1878, static electricity from wheat flour caused an explosion that destroyed the original mill). Visitors can also see Stone Arch Bridge, which spans 2,100 feet across the Mississippi river and boasts a beautiful view of St. Anthony falls, home to the University of Minnesota's hydropower laboratory.

To Minnesotans (like myself!) coming out of winter, April will feel balmy, with typical daily highs in the mid 50s, averaging almost 80°F above our coldest winter temperatures this past year. But for those of you traveling from regions below the 45th parallel, make sure you pack appropriately for nighttime temperatures in the 30s and a high chance of rain. Snow is possible in April, so check the forecast before you leave home.

Joining the April Meeting virtually instead? Don't worry about missing out — the virtual meeting platform will give you access to recorded sessions from Minneapolis, as well as an array of scientific talks delivered live online, selected from abstracts not presented in Minneapolis.

Honoring its commitment to serve as a united, inclusive "welcoming global hub" for the diverse, worldwide physics community, APS has rolled out a new, tiered registration fee structure. Although the April Meeting typically sees fewer international participants than the March Meeting, the initiative is an important step in removing barriers to attendance that disproportionately affect scientists and students in lower-income countries.

Whether you join virtually or in-person in Minneapolis, Deshpande hopes you'll have a great experience. "When scientists come together and talk to each other, and convey the excitement of their own field to others," he says, "something amazing happens."

APS encourages attendees to review the meeting's COVID-19 information and Code of Conduct. Learn more about April Meeting 2023 at april.aps.org.

Liz Boatman is a staff writer for APS News.

Letter to the Editor: Battling Freshman Physics at Caltech


Beckman Institute at Caltech Credit: Kit Leong

I applaud Donnell Walton and Carl Wieman [who authored the July/August 2022 Back Page article "What We Miss When We Focus on Physics 'Talent'"] for stressing how important teaching and preparation are for aspiring physics students. I had no idea how bad my preparation in math was until I arrived at Caltech as a freshman in 1965. The highest math course offered by the suburban New Jersey high school I graduated from was pre-calculus. Caltech offered three levels of first-year calculus, and I was put in the lowest, along with about two-thirds of my class. A couple of weeks into the term, the professor asked "How many of you have had the rudiments of integration and differentiation?" Maybe two-thirds of the class raised their hands. The professor seemed satisfied and said, "The rest of you can get it from the textbook" (by Tom Apostol). I knew immediately I was in trouble.

Freshman physics didn't help. The Feynman Lectures were the textbook, and neither it nor the problem sets — which had been adopted from an earlier physics course — made much effort to help us along in math. When I saw three integral signs in a row in one problem, I turned to my roommate and asked, "What the hell is this?" I was struggling with the idea of integration and had no idea what a triple integral meant. I kept struggling with higher math all my years at Caltech, never managing to assimilate enough to feel I had mastered it.

Only two-thirds of my entering class graduated in four years; I managed to be among them, graduating in engineering, but by then I was burnt out. After I finally settled down, I spent my career writing about science and technology, but even in my tutorials, I avoid higher math because I never mastered it.

I agree with Walton and Wieman. University physics programs need to concentrate on teaching to help equalize the inevitably unequal preparation of incoming students. Don't just drop everyone into Physics 1 without preparing them with the mathematical tools they need to understand physics. Think about incoming students as individuals with different backgrounds, and set aside time and energy to give them equal opportunity to succeed.

— Jeff Hecht (Massachusetts)

Biological Physics Comes of Age

Once an awkward confrontation between disciplines, biological physics is having its moment — and showing that life is not just a mess.

BY WILLIAM BIALEK

Physics and biology were not always separate disciplines. In the 18th century, controversy about "animal electricity" proved foundational for the understanding of electricity more generally. In the 19th century, explorations of vision and hearing intermingled with the emerging understanding of optics and acoustics. In the 20th century, the chasm between physics and biology grew wider, but there were spectacular bridges. Most famously, the work that launched our modern view of life — structures of DNA and proteins, theories of base pairing and the genetic code — was done primarily in physics departments.

The revolutionary successes of (re-)connecting physics with biology in the mid-20th century completely changed how we think about life, and even changed how biologists' work is organized. What emerged first was called molecular biology, and over the course of a generation the ideas and methods of molecular biology — grounded in physics — touched almost every part of the biological sciences. In contrast, physics itself was left relatively untouched.

Although the interaction of physics and biology did not immediately change the trajectory of physics, a small stream of physicists continued to be fascinated by the phenomena of life. I began to be (dimly) aware of all this as a student in the late 1970s. For me, the things biologists talked about were interesting, but the way they talked about them was unsatisfying. Physics was the other way: the style of thinking was attractive, and the theories elegant and powerful, but I never had an original idea about problems in the field's traditional core. It was clear that physicists were doing all sorts of interesting things connected to the living world, but these efforts didn't cohere into a community and certainly not into a recognizable branch of physics. We went to meetings where (mostly) we would find biologists working on the same systems, but not physicists asking the same kinds of questions.

If we asked our biology professors, they would argue that a physicist's search for simplicity and universality was in obvious conflict with the complexity and diversity of life. If we asked our physics professors, they might talk about a colleague who had "become a biologist," and perhaps warn that experiments in biology are messy. Discussions with both groups could easily be less polite than I have rendered them here. While physicists and biologists didn't agree on much, they did seem to agree that it was a waste of time to try doing theoretical physics in the complex context of living systems.

Forty years later, the intellectual landscape has changed radically. At the APS March Meeting, we see physicists attacking an enormous variety of problems drawn from the living world. They wrestle openly with the complexity of biological systems while searching for general principles, doing what we easily recognize as physics. More and more young people are entering the field: The number of doctoral students who write their theses in biological physics today is essentially the same as the number who wrote theses in particle physics a generation ago. Our community is no longer trapped at the interface between disciplines, and biological physics has emerged as a branch of physics. These developments are celebrated in the recent report from the National Academy of Sciences, *Physics of Life* — the first survey of the field as part of the broader decadal survey of physics.*

As a community, we have made progress not by ignoring the complexity of life's mechanisms, but by taming it, revealing underlying physics problems. An important part of what drove this progress was the interaction between theory and experiment, as in other areas of physics. Theory suggested new experiments and new ways of looking at data, and new experimental techniques made once-abstract theoretical questions concrete and urgent. We have examples from the mechanics of DNA and folding/unfolding of proteins, from the control of gene expression and the development of embryos, from the mechanics of single cells and flow of tissues, from collective behaviors in bacterial communities and flocks of birds, from networks of neurons and animal behavior, from immunology and evolution, and more.

In this spirit, my colleagues and I have studied intact biological systems whose functional behaviors are reproducible in the second decimal place, and we think this precision is key to theoretical understanding. We may be wrong about the theory, but I hope these (and many other) experiments will banish forever the physicists' old suspicion that life is just a mess.

The focus on specific systems means that we now have rather solid understanding of the physics that underlies many particular phenomena of the living world. This is wonderful. At the same time, theoretical physics is not a collection of isolated models for particular phenomena. Has the price of concrete success been the loss of once grand ambitions? I hope not.

The mechanisms of life really are complicated, and theoretical physicists are intolerant of complication. At the risk of being cartoonish, I've tried to classify the paths that theorists in our community are taking to cut through this complexity.

One possibility is that we should give up on the quantitative connections between theory and experiment that we expect in physics more broadly. Instead, we should explore theories that remind us loosely of the real thing, and hope that we can capture general trends. This was an especially common view when experiments were messier than they are now. We continue to learn from these simpler models, but the experimental situation today is vastly different. Better data demand better theory.

A deeper possibility is that the search for simplification misses the point. Real biological systems are described by models with a huge number of parameters, and there is no escape. The interesting theoretical problems are how experimental data allow us to infer the parameters, or how prediction might be possible even if not all parameters are known. This might once have seemed like giving up, but the revolution in machine learning has taught us that "over-parameterized" models can be powerful, even if we're still searching for a compelling theory of how and why this works. Progress toward such a theory should change how we think about the physics of life.

If deep networks are a guide, perhaps living systems have so many ways of solving the problems essential for survival that making a predictive theory of the underlying mechanisms is hopeless. Instead, we should focus on how one generation of solutions is related to the next — the dynamics of evolution. Importantly, evolutionary dynamics can have regularities and perhaps universalities even though individual evolutionary trajectories are unique. Statistical physics has been crucial in uncovering these regularities, and in making connections to a new generation of quantitative experiments.

A different possibility draws from statistical and condensed matter physics. Successful models for macroscopic behaviors often are much simpler than the underlying microscopic dynamics, and the renormalization group (RG) gives us a framework for understanding how this is possible. Many biological physicists hope that some RG-like arguments could help us extract more universal functional behaviors from the complex microscopic mechanisms of life, but turning this into a concrete program remains challenging. A successful example is in the analysis of collective animal behaviors, such as flocking and swarming. Related ideas come from dynamical systems theory, where behaviors near bifurcations or decision boundaries take on universal forms.

The last approach rests on the fact that living organisms are not arbitrary collections of microscopic components. Rather, they have been selected by evolution to perform functions crucial to life: converting energy, sensing the environment, coordinating movements, and more. In many cases, real organisms get close to the physical limits on their performance, as with diffraction-limited imaging and photon counting in vision, molecule counting in bacterial chemotaxis, and the efficiency of neural coding. These observations suggest a variational principle, optimizing functional performance subject to physical constraints, thus determining the parameters of very complex mechanisms without fitting. There is a long tradition of taking this approach to coding and computation in the brain, and my colleagues and I are excited about progress in using this approach to understand genetic networks.

This classification is neither complete nor orthogonal, but I hope it gives some idea of what our community has been trying to do. Each approach has its advocates and detractors, as in any lively field.

The community's experimental mastery over living systems, across scales from molecules to groups of organisms, continues to grow. One can count (almost) every messenger RNA molecule in a cell, labeled by the gene from which it was transcribed, and one can track every bird in a flock of thousands. If current trends continue, more and more of these experiments will be coupled to theory. For me, and for many of my theorist colleagues, the question is whether something unified will emerge from these efforts on specific systems — something that has the power and generality that we are used to in the rest of theoretical physics.

The emergence of biological physics is a multi-generational project. But while physics today is broader and deeper than ever before, our teaching has not kept pace. Conveying the excitement of diverse new opportunities while still transmitting the culture that unites us as physicists requires integrating new fields into the core curriculum.

The message of biological physics is that the beautiful phenomena of life connect to deep physical principles. Bacterial swimming and sensing are dominated by low Reynolds number mechanics and diffusion. Vision and photosynthesis illustrate how quantum mechanics can produce broad absorption bands rather than narrow spectral lines. DNA exemplifies the random polymer that appears in all statistical mechanics courses. These and other examples can show students that physics reaches far beyond the world of inclined planes, isolated atoms, and ideal gases, to life itself.

Beyond these now classical examples lies genuinely new physics, topics of current excitement in our field. Realizing the promise of biological physics will change how we think about life, how we think about physics, and how we think about ourselves.

William Bialek is the John Archibald Wheeler/Battelle Professor in Physics, and a member of the multidisciplinary Lewis-Sigler Institute for Integrative Genomics, at Princeton University.

*As with all Decadal Surveys of Physics, this is a "consensus report," reflecting a large committee's deliberations. I had the honor of chairing this committee, but I write here as an individual. I encourage you to read the report for a broader view.