By Randall Kamien

Ninety years ago the editor of the Physical Review, John T. Tate, proposed “a new type of journal in Physics—a journal in which would appear reports and critical comments on the various branches of current thought and research.” He continues, “[w]e recognize the value of this kind of thing in so many ways—in the symposia we have at our meetings—in the seminars we hold in our research laboratories and universities. I would hope that this journal would extend the advantages of that sort of discussion to a much wider audience.”

Endorsed by a few dozen prominent physicists, a supplement to the Physical Review was created, now known as Reviews of Modern Physics. Long before the arXiv, fax machines, and express mail, this was a timely way to disseminate and educate. The very first article, on the probable value of the physical constants by Raymond Birge in 1929, was the forerunner to the Particle Data Group’s ongoing mission. Hans Bethe, with collaborators, published a series of review articles on nuclear physics in the 1930s that came to be known as the “Bethe bible.” In 1948, Richard Feynman published his article on the path integral approach to quantum mechanics. Over the years, David Mermin has published any number of insightful reviews, and the list goes on. Articles that are over 50 years old are still a delight to read and can teach us much, from physics to pedagogy.

By Abigail Dove

With over five hundred members and counting, the APS Topical Group on Medical Physics (GMED) explores the physics underlying human health and disease—from modeling the physics of disease states to the development and optimization of medical technologies and interventions. Established in 2016, GMED is one of the newest topical groups at APS, but the tradition of physics in medicine dates back to discovery of radioactivity and emergence of technologies such as radiology and radiotherapy in the 19th century. Decades later, some of today’s hottest topics include particle transport (in scanners and tissue alike), modeling of tumor origins, development of and response to different kinds of therapies, and extrapolating the causal factors that lead to disease.

The founding of GMED began with a conversation between Princeton’s Bob Austin (out-going chair) and University of Wisconsin’s Robert Jeraj (incoming chair), who recognized the need for an organization that brings together physicists working on questions relevant to medicine. This realization was sparked in part by the National Cancer Institute’s (NCI) Physical Sciences Oncology Centers, a network of twelve research centers established in 2009 to bring together a diverse array of scientists (and particularly physicists) to rethink cancer. Austin, who headed the GMED continued on page 4

APS Membership Unit Profile: The Topical Group on Medical Physics

By Leah Poffenberger

The world’s largest physics meeting will see more than 11,000 attendees, including over 1,000 invited speakers, flocking to Boston to share research, network with future collaborators, and attend many events and workshops. The APS March Meeting will run March 4–8 at the Boston Convention and Exhibition Center (BCEC).

The 2018 Nobel Prize in Physics winners Gérard Mourou (École Polytechnique and the University of Michigan), Ann Arbor) and Donna Strickland (University of Waterloo) will speak at a special Nobel Prize session on Thursday, March 7 (5:45–6:30 PM). They will discuss the development of chirped pulse amplification, which paved the way for improved laser technology and secured them half of the Nobel Prize.

This year’s Kavli Foundation Special Symposium, themed “from unit cell to biological cell” will feature five distinguished speakers on March 6 (2:30–5:30 PM). Claudia Felser (Max Planck Institute for Chemical Physics of Solids) will speak on magnetic materials called Heusler compounds and their wide range of uses. Philip Kim (Harvard University) will share research on the emerging new physics of atomically thin structures made by stacking 2D quantum materials. A method of creating ultra-stable glass comes from research done by Mark D. Ediger (University of Wisconsin, Madison). Sharon Gleser (University of Michigan) will introduce the notion of the entropic bond in her talk “Colloidal Crystals, Quasicrystals and the Entropic Bond.” Clifford Brangwynne (Princeton University) combines biology and soft matter physics in an exploration of self-assembly of biological materials.

The March Meeting officially begins on Monday, March 4, but a number of pre-meeting activities are available on Saturday, March 2, including an orientation session for first-time March Meeting attendees (5:00–6:00 PM). A special workshop, Get the Facts Out: Changing the Conversation Around STEM Teacher Recruitment, aimed at addressing misconceptions that discourage students from pursuing careers as physics teachers, will also be held in partnership with the 2019 PhysTEC conference (2:30–5:00 PM). A Wikipedia Editing-a-thon to create Wikipedia pages for female and underrepresented minority physicists rounds out the night (6:00–9:00 PM).

The APS Prizes and Awards Ceremony will be held Monday evening (5:45–6:45 PM) followed by a welcome reception. A special outreach session on quantum information science policy “Enabling Quantum Leap: National Quantum Initiative” will also follow the Prizes and Awards Ceremony (7:30–9:40 PM).

MEETING continued on page 7
**This Month in Physics History**

**February 6, 1970: Luis Alvarez's paper in Science on cosmic rays and pyramids**

When archaeologists confirmed their discovery of a hidden burial chamber in an Egyptian pyramid, it was in some respects the culmination of a project undertaken in the 1960s. A physicist named Luis Walter Alvarez came up with the idea of using cosmic rays to map dense structures like the Great Pyramid of Giza.

Alvarez was born in 1911 in San Francisco. His father and grandfather were both physicians, and his own father was an artist. When the family moved to Chicago for young Luis’s high school years, he attended the University of Chicago, ultimately earning his PhD in physics in 1936. During his graduate studies, he built a cosmic ray telescope out of Geiger counter tubes and used it to determine that primary cosmic rays had a positive charge.

Luis's sister, Gladys, worked as a secretary for Ernest Lawrence, so after getting his PhD, he asked if there were any job openings at Lawrence’s laboratory. He offered him a job, and Alvarez joined the University of California in Berkeley to work with the cyclotron. He designed experiments to study radioactive nuclei, specifically the detection of soft-x rays from a particular type of beta decay that had been predicted but not yet observed.

During World War II, Alvarez joined the newly formed Radiation Laboratory at MIT, where he developed military applications for microwave radar. He worked on several radar projects while there, and is best known for the Ground Controlled Approach (GCA) system, which used a doppler antenna for improved resolution. Even untrained pilots could be guided through a runway landing by ground-based operators using the GCA system. It was still in use in some countries as recently as the 1980s. While testing the GCA in England in the summer of 1943, Alvarez met a young Arthur C. Clarke, then a radar technician with the Royal Air Force, and they struck up a years-long friendship.

That fall, Alvarez joined the Manhattan Project. One of his first tasks was to find a means of discovering whether the Germans had any nuclear reactors in operation. Alvarez outfitted an airplane with a system capable of detecting the radioactive gases such reactors would produce. Germany didn’t have any reactors at the time, so the mission found no such evidence, but the approach would prove to be extremely useful for intelligence gathering in the post-war era.

He took a job on the Manhattan Project: designing small instruments to measure the strength of the shock wave from an atomic bomb. He was present at the Trinity Test in 1945 and used his instruments aboard a B-29 to measure the blast energy of the atomic bombs dropped on Hiroshima and Nagasaki.

After the war, Alvarez applied his radar expertise to improve particle accelerators, leading to the construction of the Bevatron in 1945. Alvarez’s contribution was to adapt a bubble chamber so that it could work with liquid hydrogen, the better to image particle interactions. He received the Nobelist Laureate Arthur Compton, left, with young graduate student Luis Alvarez at the University of Chicago in 1933. Nobel Prize in Physics in 1968: “For his decisive contributions to elementary particle physics, in particular the discovery of a large number of resonant states, made possible through his development of the technique of using hydrogen bubble chambers and data analysis.”

His earlier cosmic ray research eventually led to his 1965 proposal that one could use muon tomography to hunt for previously undiscovered chambers in Egyptian pyramids. Alvarez and his interdisciplinary team of physicists and archaeologists placed spark chambers in a known chamber beneath the second pyramid of Chephren to detect incoming cosmic rays and measure their deflections as they hit the solid bricks of the structure. The muons would pass right through a chamber, however, registering a void in the resulting image. The Arab-Israeli Six Day War of 1967 interrupted the experiment briefly, but things resumed soon after, and Alvarez’s team continued taking cosmic ray data for the next two years. At a 1969 APS meeting, Alvarez reported that they had successfully surveyed about 19 percent of the pyramid, but had found no hidden chambers. He and his colleagues published a paper in Science to that effect in February 1970.

Alvarez’s natural curiosity often took him well outside the physics laboratory. His published photographs in 1966 of President John F. Kennedy’s assassination, Alvarez applied his expertise in optics and photo-analysis to the images. His work, outlined in an informal tutorial paper, went against many of the conspiracy theories circulating at the time. For instance, he found that the backward snap of Kennedy’s head was what would happen with a shot from behind and pointed...
Impact of Women in STEM Roadshow in India

By Sultana N. Nahar

The US Department of State funded project “Women in STEM Roadshow” (WSR), which ran from October 1, 2017 to September 30, 2018, was a huge success and made an enormous impact on the young inquisitive minds of female students from minority and disadvantaged groups in India. The project focused on inspiring students to choose STEM (science, technology, engineering, and mathematics) fields for their education and research, study in US universities for higher degrees, and use their knowledge for the development of India.

The goals of the WSR were to strengthen ties between people in the United States and India through exchanges of information, expertise, and support; to make a difference for left- and right-handers of the weak interaction. That was a significant step towards breaking the Standard Model of particle physics. In 1979, Steven Weinberg, along with Sheldon Glashow, for the unification of the weak and electromagnetic forces. Their “electroweak theory,” which became the first pillar of the standard model, asserted a symmetry between photons and other vector bosons, the force carriers of the weak interaction. That symmetry Weinberg proposed, is “spontaneously” broken as a result of interactions with other fields, making it unobservable. His theory explained several puzzles in the field, including why the weak interaction differs for left- and right-handed particles (parity violation).

In a recent essay published in Physical Review Letters, Weinberg recounted the excitement surrounding the standard model during its development in the 1960s and 1970s. Now, in an interview with Physicist, Weinberg explains initial reactions to the model and why it was called “standard.” He also offers advice to the current generation of particle physicists as they attempt to build a model that goes beyond the one that he helped build.

Your 1967 paper, “A model of leptons,” was a significant step in the standard model’s development. At the time, did you have a sense that your theory would be so transformative? I thought it might be. I really felt that I was proposing the kind of theory that might be right and Wombats going cubic

Just before the paper published, physicist Yang, a postdoctoral fellow at the Georgia Institute of Technology, along with her colleagues Miles Chan, Scott Carver (University of Tasmania), and David Hu, set out to solve one of the animal kingdom’s odd mysteries: How do wombats, a type of marsupial from Australia, make cube-shaped poop? Yang’s studies of the hydrodynamics of fluids in the bodies of animals sent her searching to see how the soft tissues in the wombats’ digestive system could combine with wetter into the odd shapes wombats leave behind.

Wombats create cubed poop in competition with nearby wombats—and the cube shape keeps the scat from rolling away, unlike the spherical or cylindrical shapes from other animals. Yang obtained intestines from Tasmania that had been collected from wombats after unfortunate run-ins with vehicles. After studying the properties of large intestines, still full of feces, Yang determined that points of varying elasticity in the intestinal wall compressed the fecal matter as it passed through, creating the cubed shapes.

Cubes are difficult shapes to create organically, and in manufacturing, cubes are generally only made by molding or cutting materials into a cube. Yang’s discovery into how wombats can naturally create cubes by compressing materia may eventually lead to new methods in manufacturing.
2018: OGA Worked with APS Members to Effectively Advance Science

By Tawanda W. Johnson

The APS Office of Government Affairs (OGA) worked with APS members throughout 2018 to successfully engage with federal agencies, elected officials, and the science policy community. In particular, the office worked with APS members who authored opinion pieces that appeared in various media outlets in key states across the country including: Kristan Corwin (Kansas); Shua Serin (Arizona); Don Q. Lamb (Illinois); and Sarit Dhar (Alabama).

Of particular note in 2018, OGA delivered the petition to key senators demobilizing student loans. Students (Arizona); Don Q. Lamb (Illinois); and Sarit Dhar (Alabama).

In an ongoing effort to achieve science policy goals that strengthen the scientific enterprise, said APS Chief Government Affairs Officer Francis Slakey. Throughout 2018, OGA surveyed APS members at meetings to determine the issues that the physics community was most concerned about, and OGA developed strategies to respond to their needs.

Federal Research Funding: In an ongoing effort to achieve sustained and robust support for federal science agencies, OGA worked with APS members, and coordinating with other science and technology organizations, advocated for increased funding through APS member op-eds and meetings with congressional offices. The result: key science agencies saw increases from fiscal year 2018 to 2019. For example, the National Science Foundation (NSF) increased its budget from $5.1 billion to $5.9 billion for fiscal year 2019. APS. Diversity also exists at the level of women (30%) in any topic. Although GMED has a historical grounding in oncology, it demonstrates the highest proportion of women in the physics of radiation therapy and medical imaging and was therefore matched by contributions to human health. Furthermore, physicists prioritizes implementing physics generating advances in medicine, it may come as a surprise that most medical physics curricula lack a dedicated education and training in medical physics specifically. He explained that a major goal of GMED is to play a leading role in promoting more explicit education and training in medical physics. For example, a survey of research topics is also mirrored in the diversity of GMED’s member. The division impressively demonstrates the highest proportion of women (30%) in any topically related field, forum, or division at APS. This diverse group of physicists exists at a scientific level in GMED, given that most medical physicists work among extremely interdisciplinary teams.

Climate change back in spotlight

The release last fall of major climate assessment brought renewed attention to President Trump’s rejection of the scientific consensus on the subject.

OGA continued on page 6

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Princeton center, recalled, “At the time it seemed crazy that the NCI centers weren’t interacting more with the American Association of Physicists in Medicine (AAPM).” That said, AAPM, the largest medical physics professional group in the US, focuses primarily on the physics of radiation therapy and medical imaging and was therefore not a natural home for physicists at the Broad Institute. Research focused on NCI centers. Entering GFED, which prioritizes implementing physics to understand and treat disease in addition to generating it—in oncology and beyond.

It’s clear that GFED occupies a unique niche in the physics community. In addition to being distinguished from AAPM in its wider lens on modeling and inter- personal and computational work, it is the unique natural convergence point for many areas of physics.”

For junior physicists still in training, GFED additionally offers valuable practical insight into the unique career possibilities that exist in medical physics. Beyond the traditional paths in research, academic training, and industry, medical physics also offers a wide range of positions and opportunities for unexpected career trajectory. Outlining these options is a major focus of GFED workshops and information sessions for younger APS members, and beginning with the upcoming APS March Meeting GFED is arranging a tour of the American medical physics research facilities at local Boston hospitals to bring this unique dimension of the field to life.

An even earlier level, culminating strong education around medical physics is a key element of GMED’s vision. The gap in education and training in medical physics—producing advances in medicine, it may come as a surprise that most medical physics curricula lack a dedicated education and training in medical physics specifically. He explained that a major goal of GFED is to play a leading role in promoting more explicit education and training in medical physics. For example, a survey of research topics is also mirrored in the diversity of GMED’s member. The division impressively demonstrates the highest proportion of women (30%) in any topically related field, forum, or division at APS. This diverse group of physicists exists at a scientific level in GMED, given that most medical physicists work among extremely interdisciplinary teams.

Beyond the vibrant community, Austin and Jeraj highlighted the intellectual opportunities associated with GFED. Jeraj gives the group’s biggest draw. While the problems in medical physics are similar in principle to those in traditional physics, they have an extra dimension of intrigue given the challenges that come with complex physics and medical systems and their many variables. Furthermore, physicists interested in machine learning, modeling, and other computational work find it compelling that the medical field is one of the most prolific generators of data; there is a wealth of possibilities in this complex and multifaceted but also highly organized data sets. Added Jeraj, ‘Many physicists may not know that their work can be translated into a medically useful finding. It’s a very natural convergence point for many areas of physics.”

By the F1! Team

A measure of predictability returned in 2018 as Congress decisively rejected the Trump administration’s proposal to reallocate funds from several federal agencies to fortify its border wall and other proposed budget cuts. However, the partial government shutdown that ensued at year’s end serves as a sobering reminder of the current political era’s volatility. In addition, the sudden surge of interest in subatomic physics is a consequence of the political era’s volatility. In addition, the sudden surge of interest in subatomic physics is a consequence of the

OGA continued on page 6

GFED continued from page 1

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An even earlier level, culminating strong education around medical physics is a key element of GMED’s vision. Given the topical group can be found here: afs.org/units/gfed/

The author is a freelance writer in Helsinki, Finland.
The Dark Energy Survey’s Six-year Exploration Comes to an End

By Leah Poffenberger

Six years ago, astronomers placed the 520-megapixel Dark Energy Camera (DECam) onto the 4-meter Blanco telescope at Cerro Tololo Inter-American Observatory in Chile. From this perch, it began a mission to map a portion of the sky with unprecedented detail and to better understand dark energy, the mysterious accelerator of the expansion of the universe. On January 9, 2019, this project, known as the Dark Energy Survey (DES), completed its data collection after gathering light from more than 300 million distant galaxies over 758 nights.

DES concluded its data taking with plenty to show for it: nearly 2,000 terabytes of raw data that collaborators can now comb through to look for clues about the nature of dark energy. The National Center for Supercomputing Applications at the University of Illinois at Urbana-Champaign has the task of storing the massive amount of data for analysis. The first step to using all that information, especially to pinpoint dark energy, is getting rid of all the noise that inevitably comes with detailed data collection.

“We’re trying to tease out the signal of dark energy against a background of all sorts of noncosmological stuff that gets imprinted on the data,” said Josh Frieman, former DES director. “It’s a massive ongoing effort from many different people around the world.”

DES has already yielded more than 200 academic papers on a variety of cosmological phenomena, thanks to the versatility of the DECam as a tool for discovery. The goal of the project was to carry out the largest galaxy survey ever, covering 1/8th of the sky. During its run, DECam was the first experiment to be able to use four methods to probe dark energy by studying galaxy clusters, supernovae, the clumpiness of galaxies, and gravitational lensing.

In 2017, DES produced a number of remarkable results, including a measurement of the dark matter structure of the universe and detecting the most distant supernova to date. DES was also one of the sky surveys that spotted the visible counterpart of gravitational waves caused by the collision of two neutron stars, helping the LIGO/Virgo collaboration usher in the era of multi-messenger astronomy.

The DECam was constructed at Fermi National Laboratory in Batavia, Illinois, before taking the trip to the NSF-funded Cerro Tololo Inter-American Observatory in Chile. The DES collaboration includes more than 400 scientists from 26 institutions in seven countries. And in 2018, the first three years of DES data was publicly released, allowing amateur astronomers from anywhere with an internet connection to analyze the data.

“Working with DES has put me in contact with many remarkable scientists from all over the world,” Antonella Palmese, a postdoctoral scientist from the University of Illinois at Urbana-Champaign, who is leading the DES data analysis effort for a variety of astro-physical observations.

“Although the data-taking for DES is coming to an end, DECam will continue its exploration of the universe from the Blanco telescope and is expected remain a front-line ‘engine of discovery’ for another ten years, continuing its usefulness for a variety of astronomical observations.”

Palmese began working on DES as a graduate student in 2015.

The DECam is expected to continue its survey of the night sky for another ten years, continuing its usefulness for a variety of astronomical observations.

With the launch of DES six years ago, James Siegrist, associate director of science for high energy physics with the U.S. Department of Energy expressed the potential of the project. “The results of this survey will bring us closer to understanding the mystery of dark energy, and what it means for the universe,” said Siegrist.

The Dark Energy Survey camera is mounted on the Blanco Telescope (center) at the Cerro Tololo Inter-American Observatory in Chile.
ALVAREZ continued from page 2

out several errors or omissions in the FBI’s official analysis. Alvarez’s son, Walter, became a geologist, and became intrigued by thin layer of clay in the strata of a limestone gorge in central Italy—marking the point where the dinosaurs went extinct, right at the Cretaceous-Paleogene boundary. Alvarez and his son collaborated with nuclear chemists at LBL, on a controversial 1980 paper suggesting an extraterrestrial cause, such as an asteroid, for that extinction event. Geologists were sharply critical, but subsequent analysis of the clay showed that it contained shocked quartz crystals, tiny diamonds, and rare minerals that only form under high temperature and pressures.

Ten years after Alvarez died, scientists discovered the Chicxulub impact crater off the coast of Mexico, lending even more support to the theory. By 2010, scientists had largely reached a consensus that this asteroid impact did indeed trigger the mass extinction that wiped out the dinosaurs. Alvarez died in 1988 from complications of surgery for esophageal cancer. But his legacy in pioneers of cosmic ray imaging techniques continues to bear fruit. In addition to Egyptian pyramids, cosmic rays have been used to map lava channels in volcanoes (like Mount St. Helens) and on other archeological sites, and to probe the structure of Brunelleschi’s dome in Florence, Italy.


Wohl, G.C., “Scientist as detective: Luis Alvarez and the pyramid burial cham-
the JFK assassination, and the end of the dinosaurs,” American Jour-
ral of Physics 75, 968 (2007).

ROADSHOW continued from page 3
to encourage students to pursue careers in STEM disciplines. “In India, women in STEM fields lag far behind their male counterparts, and the problem is acute for women from minorities and disadvantaged groups,” she said. “[Women] are interested in STEM, we just need to provide a spark for them.”

A team of four led the WSU workshops: Anil K. Pradhan (atomic astrophysicist and Director of Indo-US STEM Education and Research Center at Ohio State University(OSU)), Karen Irving (PhD in Chemistry and STEM Education at OSU), Nasreen Haque (a physicist by training and President of Intalage Inc. USA, involving teachers and students in the USA for STEM Education), and myself (physicist and founder of STEM education and research programs in many institutions in several countries and Director of WSR, OSU). We had a dedicated and efficient Indian team of local experts, local contacts, and student ambassadors in each location. Each local expert presented STEM contributions by women and explained the role of women participating in STEM fields in India.

Swaleha Naseem, a local expert in Aligarh, wrote that “after attending the workshop, the students found themselves more confident and aware of the career options available to them. They acknowledged all the speakers at the workshop for their guidance on how to improve their CVs and how they can apply to US universities for their higher education in STEM fields.”

US Consulate officials also joined us and presented inspiring stories in the Delhi, Kolkata, Hyderabad, and Kurnool workshops, while one representative spoke on EducationUSA. The US alumni shared their experiences and spoke on the benefits of studying at a US university. We invited one dedicated activist for education of women to be a chief guest in each workshop. The most notable one was the Governor of Manipur and Chancellor of Jamia Millia Islamia (a central university in Delhi), Najma Heptullah, who received her PhD in zoology and became a faculty member at age 22 before moving into government and bringing about scientific and technological changes in India.

The impact of the workshops was extremely positive for the participants. In follow-up reports on the impact of the WSR, many participants enthusiastically shared their academic progress reports to show how well they were doing in their pursuit of higher degrees in STEM fields. Most of them are achieving excellent GPAs—several ranking at the top of their class—attracting and volunteering at conferences, preparing for graduate school entrance exams, and participating in (and winning) science competitions.

“The experience of meeting such great personalities was very inspirational especially for myself,” wrote a student from Aligarh. “The speeches delivered by Nahar, Anil and others were very inspiring and built up the students’ confidence, knowledge, and the enthusiasm to explore the world.”

APS Fellow Sudana Nahar is professor of astronomy at Ohio State University, co-director for the Research and Liaison Office of the STEM ER Center, and adjunct professor of physics at AMU.

OGA continued from page 4

more action expected against sexual harassment

Efforts to combat sexual harassment in the sciences that gained momentum last year are set to continue in 2019. Leaders of the House Science Committee have introduced bipartisan legislation that would direct federal science agencies to adopt uniform policies for addressing the problem. The newly confirmed director of the White House Office of Science and Technology Policy, Kelvin Droegemeier, has also expressed support for pursuing a cross-government effort. Meanwhile, scientific societies have been revising their codes of conduct. For instance, the National Academy of Sciences is expected to advance a policy that enables it to expel members.

FYI has been a trusted source of science policy and funding news since 1989, and is read by members of Congress and their staff, federal agency heads, journal-ists, and US scientific leaders. Sign up for free FYI emails at aip.org/fyi
Solvay Conference in Brussels. My talk aroused some interest, but I wasn’t carried around the room on people’s shoulders at the time, even I knew the theory wasn’t complete. One missing ele-
ment was the proof that the theory really was renormalizable, that is, that the infinities in the calcula-
tions could be eliminated. (That proved in 1971 from Gerald ’t Hooft and others.) The other miss-
ing item was experimental verifica-
tion, which started to happen in 1973 with the discovery of neu-
tral currents in weak interactions. Also in 1973 came a theory of the strong force, called quantum chro-
modynamics. Those two pieces: the electroweak theory and the strong force formed the standard model.

When did people start call-
ing the whole thing the stan-
ard model? I don’t know exactly, but I remember using the name in 1973 during a talk in En-Provence in France. I wanted to point out to my audience that we physicists had a pretty good picture of elementary particles by then, and we could use this “standard model” as a device for interpreting experiments. Something will seem to fit any pattern. The prob-
lem is that it’s one possible pattern among many others.

I think the goal is a “final the-
ory” that explains all forces and particles. But it’s very cloudy. At this point, such a funda-
mental theory seems further away than ever, as there are hints that the required energies for seeing it are beyond our reach. It’s just a pity that the accelerator experi-
ments haven’t yet revealed any-
thing beyond the standard model, with the one exception of the neu-
trino masses.

Do you think the problems faced by particle physicists today are different from those that you faced as a young scientist? I do. It was a different situa-
tion 50 years ago. Back then, we had experimental data coming out of our ears, and a lot of it didn’t seem to fit any pattern. The prob-
lems seemed formidable, but there were so many ways to go with new theories. It really was a thrilling time to be a physicist.

Nowadays, it’s very hard to see a path of challenge that we can get our teeth into. The current puzzles don’t offer theorists many opportu-
nities to propose solutions that can be tested experimentally. Do you have any advice to offer the next generation? Winston Churchill had a motto at the beginning of World War II: “Keep buggering on.” In that spirit, I think it’s better to do something than to do nothing. My advice is to try crazy ideas and innova-
tive experiments. Something will come up.

In your PRL essay you men-
tione a lot of names of people who made exceptional contributions to the physics enterprise. I would like to make a planned gift to the American Physical Society (APS). Please contact me.

I have already included the American Physical Society in my estate plans.

Yes, please recognize me in the APS Legacy Circle.

I would like my planned gift to remain anonymous.

NAME

STREET ADDRESS

CITY/STATE/ZIP

PHONE

EMAIL

I want to support the advancement of physics.

I would like to make a planned gift to the American Physical Society (APS). Please contact me.

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LEARN MORE: go.aps.org/legacycircle

TPM continued from page 1

As with previous APS Meetings, a number of diversity events are scheduled as a part of the roundtable discussion (Wednesday, 4:00–5:00 PM), the National Society of Hispanic Physicists meetup and reception (Wednesday, 5:00–6:00 PM), and the National Society of Hispanic Physicists meetup and reception (Wednesday, 5:00–6:00 PM). Also on Wednesday, there will be an Education and Diversity reception (7:00–8:00 PM). On Tuesday, March 5, APS Reviews of Modern Physics (RMP) cel-
brates 90 years with talks from the authors of popular RMP papers and a champagne toast (7:30–9:00 PM). Editors from all APS journals will also be available Tuesday from 4:30–5:30 PM to answer questions and discuss the Physical Review journals. Also on Tuesday, March 5, APS

Indeed, as the scope of APS

measures its impact on society and the sciences, its publications, and its role in scientific outreach, Reviews of Modern Physics is taking steps to broaden the definition of “Modern Physics.” We have appointed an editor to cover climate science, we are expanding our solicitation articles on fluids, applications, and mate-
rials, and we continue to expand into new areas, “physics broadly construed.” We have the distinct advantage that we are a journal that can plot our own course—we need not be swayed by the desire to promote our articles to the popular media and we can publish articles for our true constituents. Our sin-
cerely thanks go out to authors, referees, and editors who continue to make this possible.

Randal D. Kamien is the Lead Editor of Reviews of Modern Physics and Vicki and William Abrams Professor in the Natural Sciences in the Department of Physics and Astronomy, University of Pennsylvania.

Reference


For more on the history of Reviews of Modern Physics, see the February 2019 special issue of Physics Today (physicstoday.org).

At both the March and April Meetings this year, Reviews of Modern Physics will host special symposia to encourage excellent scientific communication, celebrate our 90th anniversary, and look for-
ward to the Reviews of the Future.

APS March Meeting - Reviews of Modern Physics: The First 90 Years, Tuesday, March 5, 7:30–9 PM, Grand Ballroom A, Westen Boston Warwick. For the lat-
est information on the APS April Meeting sessions, see aps.org/meetings/april/
A s we contemplate our world today and its future, we cannot help but marvel at the incredible advances in our daily lives brought about by industrial physics. A quick glance around an office reveals a smartphone, computers, printers, LED lights, digital sound systems, flash drives, with microelectronics, nanomaterials, lasers, and micro-magnets. These are transformative technologies and have created the 21st Century as we know it. How has this happened and what role does industrial physics play? To help answer these questions, the APS Industrial Physics Advisory Board has just released its report on The Economic Impact of Industrial Physics on the U.S. Economy, available at aps.org/programs/industrial/impact-economy.cfm.

The challenging findings of the study show that an estimated 12.6% of the U.S. economy can be ascribed directly to the practice of industrial physics, among other impacts summarized below.

### Defining industrial physics
- Physicists with degrees in physics who work in industry
- Engineers and other scientists and technical people who employ physical principles in their work
- Use of fundamental physical principles to design and manufacture physical products and systems
- Emerging knowledge of new physical principles that lead to innovative and new products and services

### Recommendations to Physics Communities to Promote the Future of Industrial Physics

- Liaisons; industrial professorships; industrial lectures at schools.
- Internships; cross-department thesis topics; industrial support physics. The following recommendations build on that existing work.
- Hypothesized physics should be encouraged as industry routinely combines multiple disciplines in developing new products and services.
- Government tech-transfer policies and procedures should be continually reviewed for effectiveness.
- National physics-related facilities should have resources readily available for industrial use, including commercially-conducive intellectual property processes.
- U.S. patent protection procedures should be periodically reviewed for competitiveness.
- SBIR/STTR programs, especially focused on entrepreneurial needs, should be strongly supported.
- Immigration policies should ensure that the brightest students are incentivized to study physics in the U.S. and are able to work for U.S.-headquartered companies after graduation.

### Industry
Industries can take actions that catalyze the flow of physicists and physics to companies in the future. APS can help encourage industrial engagement via:
- Improved interactions with two-year, undergraduate, and graduate physics education programs, such as lectures, visiting professorships, participation in thesis committees, talks and attendance at APS Sectional meetings.
- Internships for physics undergraduate and graduate students; industry can work with organizations such as APS to develop guidelines and suggestions for effective programs.
- Involvement in local pre-college STEM efforts, with special emphasis on reducing entry barriers related to minority, gender, or socio-economic status.
- Education of industrial HR departments about capabilities of students with physics degrees and how to recruit them.
- Interactions with major-government-industry programs, such as the NIST Manufacturing Extension Partnership (MEP).

### Industrial physics
Industrial physics is a major contributor to the economic well-being of the United States.

- Industrial physics contributes approximately 12.6% of value added to the U.S. economy in 2016, about 2.3 trillion dollars.
- Direct employment related to industrial physics was about 11,500,000 people in 2016, which accounts for almost 6% of total U.S. employment.
- U.S. exports by physics-based sectors are about 1.1 trillion dollars (2016), which is approximately 20% of the value added (GDP) produced by those sectors.
- In the period 2003 to 2016, approximately 70,000 degree physicists joined industry
- Between 2010 and 2016, over 340,000 patents with the classification of physics were granted to U.S. companies
- In 2015, U.S. physics-based companies made internal R&D investments of over 150 billion dollars
- Between 1966 and 2016, the value added contributed to GDP by the physics-based sectors of the U.S. economy grew by a factor of 22. At the same time, the GDP grew by a factor of about 4 (both in 2016 constant dollars).

### American Physical Society
- The following proposals align directly with the new APS Strategic Plan goals. The APS Industrial Physics Advisory Board is ready to provide support and additional information as appropriate.
- Make a priority of retaining industrial physicist members, especially early career members.
- Offer 1- or 2-day expert meetings strongly focused on topics of industrial physics interest to address the time and travel constraints of industrial physicists.
- Provide industry-focused publications—peer-reviewed, technical journals as well as popular content such as the non-defunct Industrial Physicist magazine.
- Provide career guidance meetings aimed at early-career industrial physicists, such as project management, business basics, and people management.
- Consider establishing a Center for Entrepreneurial and Industrial Physics to foster innovative programs on teaching and promoting entrepreneurship and industrial careers.
- Provide Up-to-Speed physics information—TED and other online talks, paper bundles; print-on-demand articles and book excerpts relevant to hot topics of interest to industrial physicists.
- Encourage sections to involve local industry in their meetings.

### Students and Practicing Physicists
More than 50% of graduating physicists enter industry to find exciting and rewarding careers. The companies for which they work and the careers they pursue range from highly entrepreneurial technology start-up firms to well-established technology leaders to finance and banking to data analytics. The diversity of possibilities reflects the power of modern physics education, which emphasizes formulating the right questions and being rigorous in developing answers based on facts. Some suggestions for students to expand their physics horizons include:
- Talk to physicists in industry, and not just technological or scientific industries; hear directly about what working in industry is like, both in terms of rewards and challenges.
- Expose yourself to topics of industrial interest such as new technologies, entrepreneurship, and applied physics; take advantage of APS meeting sessions on industrial and applied physics.
- Pursue internships in industry.
- Take advantage of APS partner services for mentoring opportunities, job searches, interview and resume hints and help, and much more.
- Consider taking an introductory business course or two.
- Maintain your APS membership—remember once a physicist, always a physicist!

### Call to Action
Industrial physics is alive and well and provides innumerable benefits to physicists, physics, and society. It is critical to nurture the industrial physics enterprise and to ensure that it remains a major source of innovation, economic growth, and a positive influence on the future. All physicists, regardless of their interests, can participate in the rich environment. Let’s help its continued success.

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