Radiations

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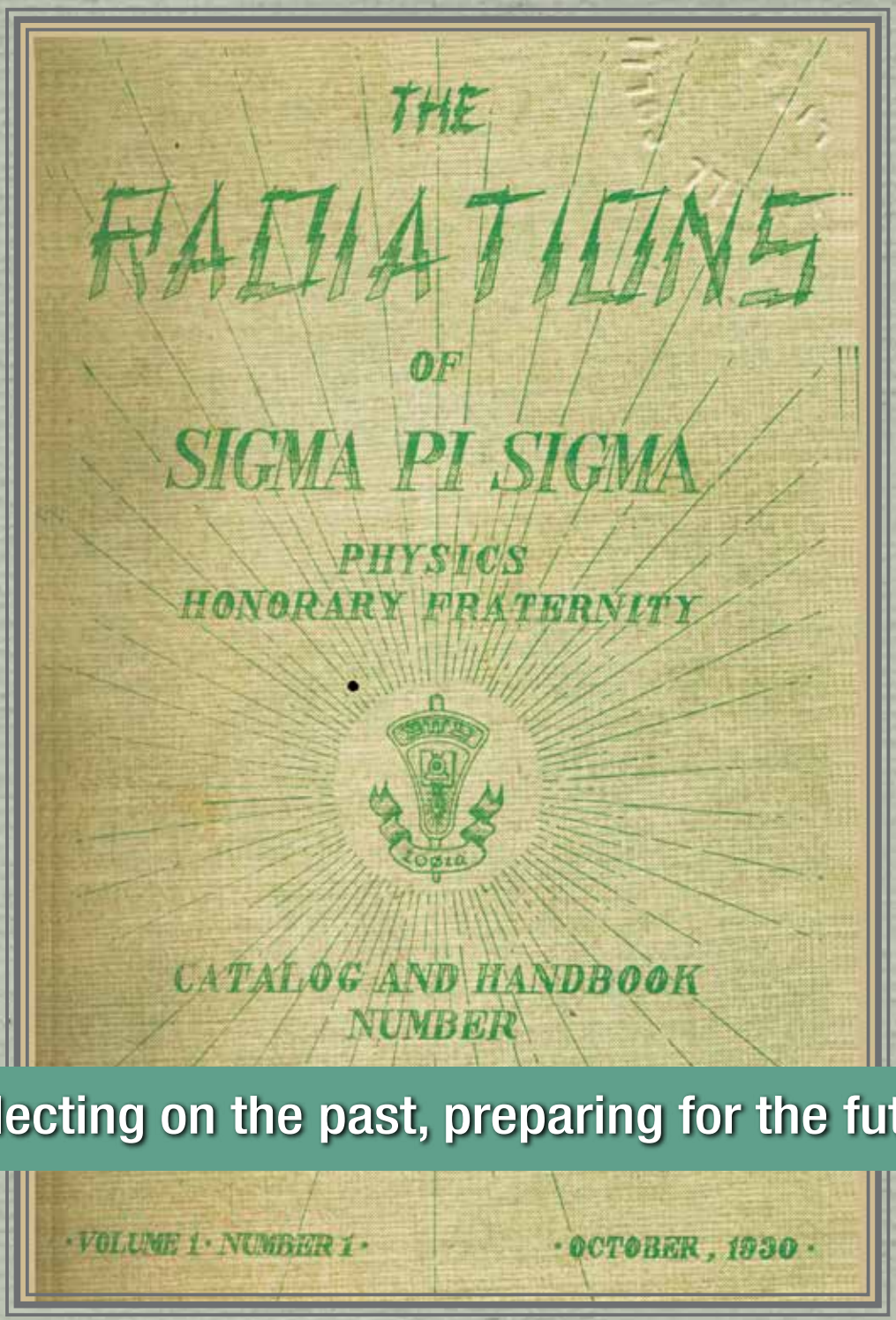

Reflecting on the past, preparing for the future

- The Context of Scientific Progress: World War I and the Theory of General Relativity
- Sharing the Spotlight: Resources for Correcting the Narrative of Physics History

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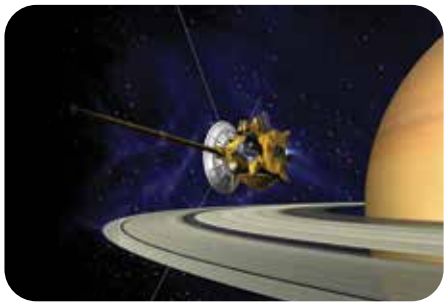

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ON THE COVER

In honor of this issue reflecting on the past of Sigma Pi Sigma, the cover features the cover of the very first issue of The Radiations of Sigma Pi Sigma published in 1930.

Image courtesy of AIP.

Radiations

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Letter from Congress Chair

Reflecting on the 2010s and Absorbing Wisdom for the 2020s

by Samantha Pedek, Physicist, 2021 Sigma Pi Sigma Congress Co-Chair, 2017 SPS Intern

Samantha Pedek
Image courtesy of SPS

Welcome to the 2020 Spring edition of Radiations! Since the theme of this issue is "Reflecting on the past, preparing for the future," I thought this would be a great opportunity to think back on the past 10 years. For many of us in the United States, the start of the 2010s was defined by a devastating recession. It took most of the decade to fight our way out of that recession, and it would be a shame not to acknowledge that struggle. Yet the past decade was also one of innovation and creativity. The 2010s brought the iPad, rideshare apps like Uber and Lyft, money transferring apps like Venmo, smart home assistants and smart watches, and social media platforms such as Instagram and Snapchat. The 2010s also produced a plethora of pop culture references through television shows like Glee, Game of Thrones, and Orange is the New Black; a rebooting of the Star Wars franchise; the end of the Harry Potter saga; and an ending to the Avengers that ripped our hearts out. Life today has been drastically influenced by the past 10 years; even the way we communicate has adapted to include memes and emojis.

The scientific community also experienced a decade of great prosperity and adaptation. Some of the most notable scientific developments were the detection of the Higgs boson and gravitational waves, the observation of cosmic neutrinos, the Curiosity rover's exploration of Mars (I recently learned that Curiosity sings "Happy Birthday" to itself, which is amazing), the Hubble eXtreme Deep Field image, and, most recently, the very first image of a black hole. The scientific achievements of the last decade reflect the work of large, mostly international collaborations that include dozens of institutions, or more. This is reflected in the dawning of a new era of astronomy—multimessenger astronomy. Observations of the same event in electromagnetic waves, gravitational waves, and neutrinos can lead to a better understanding of the universe and require the cooperation of many people from all over the globe. This spirit of collaboration is what makes the scientific community successful.

As we begin a new decade, let us not only reflect on where we are today but also set goals and expectations for the next 10 years. Sigma Pi Sigma is approaching its centennial anniversary. Because of this, I encourage you to reflect on what it means to be a Sigma Pi Sigma member. My challenge to you is to be an advocate of science. As we face a climate crisis and a general public that is losing trust in science, it is our responsibility, as Sigma Pi Sigma members, to bring our experiences and expertise into the conversation. Take the time, and the patience, to share your passion for physics with people not affiliated with the scientific community. It is easy to get so wrapped up in our lives, our studies, and our research that we forget how important it is to reach out to nonscientists in a meaningful way.

Thank you, and enjoy this issue of Radiations.

The Next 100 Years of Physics and Astronomy:

Supporting Sigma Pi Sigma and the Society of Physics Students

by Director B. R. Conrad and the Student Leaders of SPS and Sigma Pi Sigma

Sigma Pi Sigma was originally formed to help strengthen the community of physics and astronomy students nearly 100 years ago. Despite its age, it continues to play a fundamental role in building strong departments and growing the next generation of community leaders by directly enabling student- and faculty-led initiatives. By providing student leaders with opportunities to grow both professionally and interpersonally, Sigma Pi Sigma and SPS can support these unique initiatives at over 800 different schools across the globe. As a cornerstone of the physics and astronomy community, we aim to help students and faculty build an organization that represents who they are and their values.

We asked student members to share in their own words why they choose to support SPS and Sigma Pi Sigma.

"Supporting SPS is important because it is an organization which is actually transforming the lives of students aspiring to become professionals in physics. So many important skills are not taught in the classroom, and SPS constantly strives to provide these opportunities for students to develop the vast range of research and communication skills essential to becoming a strong contributing member to the scientific community. Without SPS I would not have the abilities that I do today nor the confidence to continue the pursuit of my goals."

Brigette Smith, 2019, SPS leader at Coe College and Associate Zone Councilor, Zone 11

"SPS is an organization for undergrads that study physics and astronomy. The only requirement to join is to have an interest in those topics, which makes this club super inclusive. It can be scary for younger students who are just starting to enter the field, so being surrounded by students who are going through the same experiences or have gone through them recently can be helpful and comforting in a way. SPS provides this community of people who are excited about their studies and are willing to share their excitement with their peers to help them figure out how to navigate physics and astronomy or even figure out if it is the right fit."

Nour Ibrihim, SPS leader at Embry-Riddle Aeronautical University – Prescott and 2019 SPS Outreach Intern, 2021 Physics Congress Planning Committee

AIP
American Institute of Physics

The American Institute of Physics is a federation of scientific societies in the physical sciences, representing scientists, engineers, educators, and students. AIP offers authoritative information, services, and expertise in physics education and student programs, science communication, government relations, career services, statistical research in physics employment and education, industrial outreach, and history of the physical sciences. AIP publishes *Physics Today,* the most closely followed magazine of the physical sciences community, and is also home to the Society of Physics Students and the Niels Bohr Library & Archives. AIP owns AIP Publishing LLC, a scholarly publisher in the physical and related sciences. www.aip.org

Member Societies

Acoustical Society of America
American Association of Physicists in Medicine
American Association of Physics Teachers
American Astronomical Society
American Crystallographic Association
American Meteorological Society
American Physical Society
AVS Science and Technology of Materials, Interfaces, and Processing
The Optical Society
The Society of Rheology

Other Member Organizations

Sigma Pi Sigma
Society of Physics Students
Corporate Associates

Connect with Sigma Pi Sigma

LinkedIn
www.linkedin.com/groups/Sigma-Pi-Sigma-physics-honor-142619

Facebook
www.facebook.com/groups/sigmapisigma

Donate
donate.aip.org

Your Dollars At Work

"SPS has connected me to physicists from across the country and to a national community I didn't even know existed. SPS matters because physics is more than just classes."
Nathan Foster, former SPS member at Tufts University and 2018 Science Policy News Intern

"As someone who went to a smaller institution with no Sigma Pi Sigma chapter, our SPS group was the reason I got involved with the department, met other students in the program, and participated in opportunities that helped jumpstart my career. I'm not sure I could have done all that without SPS."
Riley Troyer, former SPS leader at University of Alaska Fairbanks and 2019 Physics Congress workshop leader

"When I look back on my college experience and think about the 'good times,' 9/10 of those experiences were connected to my SPS chapter. The experiences I had with my SPS chapter were fun, but they also prepared me for graduate school. Without the experiences I had in SPS I wouldn't be where I am today."
Tori Eng, former Associate Zone Councilor, Zone 11, and 2017 SPS History of Physics Intern

While the American Institute of Physics supports the SPS and Sigma Pi Sigma organizations, we rely on the donations of community members to directly fund student grants, awards, and scholarships. Several funds have been established to directly impact the community of Sigma Pi Sigma and SPS chapters and support student-led initiatives. Each fund addresses a different need within the community:

All images are courtesy of SPS.

Congress Student Travel Fund

Supports students traveling to the 2021 Physics Congress in Washington, DC, by underwriting airfare, lodging, registration, and meals. Often students use these funds to bridge the gap between fundraising and attendance.

Sigma Pi Sigma Annual Fund

Provides merit- and need-based scholarships for undergraduate students as well as grant funding for chapters to conduct science outreach in their local communities. Awards include support for future teachers and those that display excellence in service.

Sigma Pi Sigma Endowment

Supports society-wide initiatives, professional development programs, and ensures that students in future generations will have the opportunity to participate in Sigma Pi Sigma and SPS events.

Mather Science Policy Internship Fund

Continues the work of Nobel laureate John Mather to bring science students to Capitol Hill for summer internships to bridge the gap between scientists and policymakers through science policy.

Sigma Pi Sigma Centennial Fund

In celebration of the upcoming centennial of Sigma Pi Sigma in 2021, a new endowment is being established to secure the future of the Physics Congresses for generations to come. This fund will be used to establish an endowment to underwrite future Physics Congresses.

The linked but distinct societies of Sigma Pi Sigma and SPS are volunteer driven, and it is only through the support of our community that we are able to ensure that future generations have experiences that mirror the comments of the student leaders above. We each play our own part in making the community the welcoming and accepting place it needs to be, and I thank you for that. I invite you to join us in contributing to the next generation and the second 100 years of Sigma Pi Sigma. ●

Brad R. Conrad

donate.aip.org

Cultivating Service in the Name of Physics

by Natalie Rugg, SPS Chapter Coordinator, Brown University

Following the Mega High Energy Chocolate event at PhysCon 2019, student volunteers from Brown (pictured here) helped with cleanup—an example of the community of support cultivated at the university. Image courtesy ofthe Brown University SPS chapter.

Undergraduate physics students at Brown University are exactly as you'd expect them to be: passionate about the subject, excelling at what they do, and challenging themselves by tackling advanced material (creating new courses to explore even more).

Of course, physics isn't an easy path for anyone, even with these aforementioned traits. What really sets Brown and its students apart is that despite challenging courses that endow graduates with a competitive skill set, we don't compete with each other. There is a pervasive collaborative environment that in no way feels fabricated or circumstantial.

We've had something called a Physics DUG (Department Undergraduate Group) for quite a few years now. Through this organization we aim to provide physics students with resources, an inclusive community, and academic, advisory, and social programming. Only recently have we joined the Society of Physics Students, plunging into the national physics scene as the host chapter of PhysCon 2019. Now I believe we're ready to formally introduce a new aspect of our mission: service.

Brown is creating a Sigma Pi Sigma chapter to recognize academic excellence and perseverance and to reward and encourage service in the name of physics. Already we see students volunteering to lead study groups, working as undergraduate TAs, and meeting with prospective students to answer their questions. On a larger scale, undergraduate physics students recently volunteered for Providence's second annual Big Bang Science Fair, running educational events aimed at children and the general public. It is this type of service to physics as a discipline that our SPS chapter would like to celebrate and promote through joining the Sigma Pi Sigma national honor society. ●

Fall 2019 Chapter Awards

Congratulations to the following winners of the Fall 2019 Chapter Awards. These awards are made possible in part by generous contributions from Sigma Pi Sigma alumni. For examples of past award-winning projects, visit **www.spsnational.org/awards/chapter-awards**.

Future Faces of Physics

Future Faces of Physics Awards are made to SPS chapters to support projects designed to promote physics across cultures. The goal of the Future Faces of Physics Award is to promote the recruitment and retention of people from groups historically underrepresented in physics.

Abilene Christian University
Physics Roadshow
Elizabeth Jennings (Leader)
Larry Isenhower (Advisor)

Colorado School of Mines
Future Faces of Physics with CSM SPS
Dylan Honors (Leader)
Charles Stone (Advisor)

Ithaca College
Promoting Indigenous Voices in Big Science
Robert Melikyan (Leader)
Preston Countryman (Advisor)

John Carroll University
STEMMED: Science and Service
Kyle Blasinsky (Leader)
Danielle Kara (Advisor)

Marshall University
Astrophysics in the Appalachians: A Perspective on Pulsars by Dr. Natalia Lewandowska
Jacquelyn Sizemore (Leader)
Sean McBride (Advisor)

Universidad de Puerto Rico – Mayagüez
Physics for Everyone
Génesis González (Leader)
Erick Roura (Advisor)

University of the Sciences
Fall in Love with Physics!
Alyssa Petroski (Leader)
Roberto Ramos (Advisor)

Marsh W. White

Marsh W. White Awards are made to SPS chapters to support projects designed to promote interest in physics among students and the general public. The Marsh W. White Award dates back to 1975 and is named in honor of Dr. Marsh W. White for his long years of service to Sigma Pi Sigma and the community.

Adelphi University
Lab for Kids
Carissa Giuliano (Leader)
Matthew Wright (Advisor)

Augustana College
Spring Into Physics!
Emmalee Pentek (Leader)
Cecilia Vogel (Advisor)

Georgia Institute of Technology
Spark, Spin, Freeze!
Matthew Barroso (Leader)
Edwin Greco (Advisor)

Ithaca College
Bots with Buds
Oluwasekemi Odumosu (Leader)
Jerome Fung (Advisor)

Missouri Southern State University
Promoting Physics Outreach with Interactive Demos
Jeremiah Wald (Leader)
Jency Sundararajan (Advisor)

New Jersey Institute of Technology
Stimulating Minds by Simulating Physics
Jonpierre Grajales (Leader)
Andrei Sirenko (Advisor)

Radford University
Electrifying Electronics
Alex Anderson (Leader)
Rhett Herman (Advisor)

Rhodes College
Becoming Best Buddies with Physics: The Amazing Race
Gia Pirro (Leader)
Brent Hoffmeister (Advisor)

Stony Brook University
High School Physics Engagement Labs
Max Podgorski (Leader)
Robert McCarthy (Advisor)

Towson University
Science Fridays
Colin Hamill (Leader)
Jeffrey Simpson (Advisor)

University of Central Florida
Improving Outreach Through Illuminating Optics
Zainulabedin Khan (Leader)
Costas Efthimiou (Advisor)

University of Iowa
Children's Book Outreach
Genna Crom (Leader)
Jasper Halekas (Advisor)

University of Southern Mississippi
Physics for All
Swapnil Bhatta (Leader)
Michael Vera (Advisor)

University of Texas – Dallas
Comet Rocket Competition 2020
Austen Adams (Leader)
Jason Slinker (Advisor)

University of the Sciences
How Can Physics Power Your Life?
Gopal Goberdhan (Leader)
Roberto Ramos (Advisor)

SPS Chapter Research

The SPS Chapter Research Award program provides calendar-year grants to support local chapter activities that are deemed imaginative and likely to contribute to the strengthening of the SPS program.

American River College
Polarimetric Measurements of the X-Ray and Gamma-Ray Background Noise in the Stratosphere
Kaylianne Jordan (Leader)
Paulo Afonso (Advisor)

Ithaca College
Rockets vs. Kinematics
Robert Melikyan (Leader)
Preston Countryman (Advisor)

Rhodes College
MMOD Hardware Testing and Communications for the Rhodes College CubeSat Program
Giuliana Hofheins (Leader)
Brent Hoffmeister (Advisor)

South Dakota State University
Partially Lithiophilic Non-Conductive Matrix as Lithium Host for Lithium Metal Battery
Abdullah Al Maruf (Leader)
Robert McTaggart (Advisor)

Suffolk University
Neutron Energy Distribution of an AmBe Source at the MGH Proton Center
Phuc Mach (Leader)
Walter Johnson (Advisor)

Universidad Autonoma de Ciudad Juarez
Construction of a Radio Telescope for the 21-cm Hydrogen Spectral Line
Fernando Terrazas (Leader)
Sergio Flores (Advisor)

Sigma Pi Sigma Chapter Project

The Sigma Pi Sigma Chapter Project Award provides funding of up to $500 for chapter inductions and events.

Abilene Christian University
50th Anniversary of ACU Physics – Sigma Pi Sigma Induction
Benjamin Edwards (Leader)
Larry Isenhower (Advisor)

Henderson State University
Zone Wide Sigma Pi Sigma Induction
Joseph Dees (Leader)
Shannon Clardy (Advisor)

St. John's University
The Engineer's Catapult
Seychelle Khan (Leader)
Charles Fortmann (Advisor)

University of Central Florida
UCF Induction Ceremony
Zainulabedin Khan (Leader)
Costas Efthimiou (Advisor)

University of North Alabama
Sigma Pi Sigma Induction and Alumni Event
Mel Blake (Leader and Advisor)

University of the Sciences
Sigma Pi Sigma: Celebrating the Culture of Scholarship and Service in Physics
Dan Fauni (Leader)
Roberto Ramos (Advisor)

2018–19 SPS Outstanding Chapter Advisor

The SPS Outstanding Chapter Advisor Award is the most prestigious recognition given each year by SPS. The following SPS advisors were nominated by their students, colleagues, and departments in recognition of their dedication to furthering the mission of SPS. The winner receives a total of $5,000 for themself, their chapter, and their department. The winner was officially recognized at the Winter 2020 AAPT Meeting. The runner-up's chapter receives a $100 gift card for a pizza party and other chapter activities. Learn more at https://www.spsnational.org/awards/outstanding-chapter-advisor.

Winner
Alina Gearba-Sell,
United States Air Force Academy

Runner-Up
Peter Sheldon,
Randolph College

Nominees
Cecilia Vogel, Augustana College
Cristian Bahrim, Lamar University
Jason Slinker, University of Texas-Dallas
Larry Isenhower,
Abilene Christian University
Mark Siemens,
University of Denver
Matthew Wright, Adelphi University
Michael Dowding, South Dakota School Mines & Technology
Ronald Kumon,
Kettering University A & B
Shannon Clardy,
Henderson State University
Tamara Young,
University of Utah
Wayne Trail, Southwestern Oklahoma State University

A Growing "Physics Phamily"

by Matt Mancini, SPS Chapter President, New College of Florida

New College of Florida in Sarasota is a small liberal arts school that focuses on academics to prepare students for graduate work and professional opportunities. As such, our physics students were seeking ways to become more involved in the national physics conversation, and there seemed to be no better means of accomplishing this goal than by founding an SPS chapter.

Following up with the addition of a Sigma Pi Sigma national honor society, New College's physics students have since developed a tight-knit community that seeks to help its members achieve success in the field. Students accomplish these goals by hosting homework workshops and tutoring sessions and by conducting outreach demos in local schools throughout the year.

For example, in 2019, chapter president Matthew Mancini and treasurer Alex Sturzu went to Sarasota High School (SHS) to demonstrate the interferometry principles underpinning LIGO and exhibit the dazzling geometric patterns of cymatics. Students from every level of physics offered by SHS also had the opportunity to participate in a Q&A session on what higher education in physics looks like from day to day and how to develop an improved understanding of career paths in the field.

Ultimately, SPS/Sigma Pi Sigma has had an incredibly positive effect on the building of community within our physics discipline. The chapter has facilitated the development of daily meeting space in which students can discuss and work on class assignments and explore their interests in physics. Almost every day there's now lively debate on various topics such as the ontological foundations of quantum mechanics (or lack thereof) or whether QFT or GR dominates.

SPS/Sigma Pi Sigma at New College has provided fertile soil for the growth of our "Physics Phamily"—and we could not be happier. ●

TOP: Physics professor Mariana Sendova instructs student Jay Mosher on conducting vibrational analysis of Raman spectra. Photo courtesy of New College of Florida.

RIGHT: Physics professor Mariana Sendova (center), SPS president Matt Mancini (left), and treasurer Alex Sturzu (right) work together on the CRAIC microspectrophotometer and discuss the analysis needed on newly received glass samples. Photos courtesy of New College of Florida.

Where Do You Get Your Science News?

by Kayla Stephens, SPS Programs Manager

According to the Pew Research Center, most Americans are receiving their news less from print newspapers and more through television, online, and social media apps.[1] With information so readily available through a search engine, a touch of a button, or simply viewing trending headlines on social media, we wanted to know the most popular science news outlets among Sigma Pi Sigma members.

Sigma Pi Sigma asked our members where they get their science news. Check out the answers below, and let us know what you think by emailing us at **sps@aip.org**.

Sigma Pi Sigma's Top Five

PHYSICS TODAY

Physics Today is the flagship publication of the American Institute of Physics. The mission of the magazine is to be a unifying influence for the diverse areas of physics and physics-related science. *Physics Today* offers full news coverage and analysis, fresh perspectives on technological advances and groundbreaking news, a forum for the exchange of ideas within the scientific community, and so much more. For additional information, visit **www.physicstoday.org**.

Quanta magazine

Quanta Magazine is a nonprofit foundation–funded publication that combines the complexities of science with storytelling. The name *Quanta* comes from Albert Einstein's reference to photons as "quanta of light," which showcases the magazine's goal to "illuminate science." Articles address topics in mathematics, theoretical physics, theoretical computer science, and the basic life sciences. To learn more, visit **www.quantamagazine.org**.

ScienceDaily

ScienceDaily was founded in 1995 by husband and wife Dan and Michele Hogan, and aims to be a top science news resource, primarily by aggregating science-related press releases. You can find headlines on topics ranging from medical sciences and health to physical sciences, new technologies, and much more. Articles are posted daily from universities, scientific journals, and research organizations. For more information, visit **www.sciencedaily.com**.

Science

Science is published by the American Association for the Advancement of Science, AAAS, and was founded in 1880. The journal publishes news, commentary, and peer-reviewed research. It is well known for publishing the entire human genome for the first time, never-before seen images of the Martian surface, and the first studies tying AIDS to human immunodeficiency virus. *Science* has a history of publishing highly cited articles. For more information, visit **www.sciencemag.org.**

FYI

FYI is an authoritative news and resource center for federal science policy from the American Institute of Physics. The FYI team reports on physical science developments in Washington, DC, and beyond, seeking to illuminate how policy affects science and how science shapes policy. Visit **www.aip.org/fyi** for more information.

Other popular science news outlets highlighted by members:

BBC NEWS

BBC Science – Based in the UK, the BBC aims to be an impartial and independent public service broadcaster while educating and entertaining millions across the world.

The New York Times

The New York Times – Established in 1851, the *Times*'s mission is to seek the truth and help people understand the world through independent journalism. Their science section includes developments about space, climate change, animal behavior, and more!

reddit

Reddit – Reddit considers itself to be the front page of the internet. In the *New Reddit Journal of Science*, viewers can engage in endless conversation and connect over topics that they care most about!

NATIONAL GEOGRAPHIC

National Geographic – For 131 years, *National Geographic* has aimed to ignite their audience through groundbreaking storytelling from the world's top scientists, explorers, photographers, and filmmakers.

References

1. Mitchell, Amy, Jeffrey Gottfried, Michael Barthel, and Elisa Shearer. "How Americans Get Their News." Pew Research Center's Journalism Project, July 7, 2016. https://www.journalism.org/2016/07/07/pathways-to-news/.

Sigma Pi Sigma – A Departmental Legacy of Fellowship (Part 2)

by Brad R. Conrad, Director of SPS & ΣΠΣ

What *is* in a name? Sigma Pi Sigma was founded in 1921 at Davidson College as a department-centered group that rewarded "high aim," encouraged service to the community, and improved departmental fellowship. The benefits of this new society were quite apparent to those that visited Davidson, and the 1920s ended with a rapid expansion of the society which continues to this day.[1] Beyond merely adding additional chapters, this period was a phase transition of sorts, as the composition of the society began to shift from a few schools in close communication with each other to a much wider-reaching initiative spanning graduating cohorts. There became a need for society discussion and member news to be spread across dozens of schools with hundreds of members, past and present. Many of those graduating needed a mechanism to remain connected to not just their alma mater but each other, which is still the case today.[2] To answer the question of how to connect members spanning institutions and generations, the Sigma Pi Sigma Executive Council chose a freely available, member-focused publication which would contain letters from society leaders, community information, and chapter updates.

Below is an excerpt of an editorial from the first issue of the Radiations of Sigma Pi Sigma, which was published in October of 1930[3] and written by Dr. Marsh White himself[4]:

> "*Our selection of the name the Radiations of Sigma Pi Sigma for this magazine is purely provisional and subject to change. It seemed appropriate to us. What is your reaction? One of our prominent and greatly interested members wrote some time ago concerning this designation: 'No more happy title was ever chosen for a journal. Only a physicist can realize the significance of the symbolism. Yet it is obvious that from such an organization as Sigma Pi Sigma there are always these intimate penetrating rays that pervade our entire being and our laboratories. They are invisible; they may be unnoticed by an outsider; but they affect every moment of our life. They arise from electronic encounters from sparks within ourselves and between the members of the fraternity. A laboratory in which the fraternity is organized is never inactive and never at a low potential but is alive at the core. The attendant phenomena are numberless; the production and consumption of energy is tremendous and from those transformations of energy arise new theories, new concepts and new vigor. But most striking is the fact that we all live and breathe in an atmosphere which is vibrating at a high frequency and in which we all have luminous fluorescent faces activated by the radiations of Sigma Pi Sigma. Such an atmosphere is the most precious asset of any university.'*"

The field has changed greatly since this was written in 1930, but the atmosphere in which physics departments flourish largely remains the same. Our undergraduate studies affect us deeply, forever changing how we approach the world; however, it is our interactions with each other, our "luminous fluorescent faces" that often have the longest impact.

If SPS and Sigma Pi Sigma were not created when they were, they would have been reinvented to fulfill a fundamental need within physics and astronomy departments: a desire to academically excel, aim high, and share in the pleasure of discovery with colleagues. This speaks to the unique place our organization occupies within departments and for students across a century, as SPS is for many students their first support network and their entry into the broader physical sciences.

The field has changed through the decades, and the work of Sigma Pi Sigma chapters has developed with the times. There is evidence of the first SPS/ΣΠΣ lounge, a closely guarded tradition for many departments, as far back as 1930 at the University of Kentucky.[5] To quote the chapter historian, "All are rightfully proud of this 'social center' in the department. It serves a purpose which is very essential to the lives of all, even the physicists."[5] And, knowing how student spaces go, the couch featured in the Lambda chapter photo might have been repurposed and still in use in an SPS lounge somewhere else to this day.

As the membership became more diverse, so too did its founding principles. While some groups did not induct women at the time of the founding, *Radiations of Sigma Pi Sigma* provides us with many examples of Sigma Pi Sigma chapters doing just that, spanning back to our first chapters.[6] Additionally, the first female editor of the publication, Vivian Johnson of Purdue University, was announced in the October

Charter Members and Installing Party, Upsilon Chapter

Lambda's clubroom, a feature other chapters may well emulate

1937 issue.[7] Through deliberation with the broader collection of chapters, induction criteria for service were strengthened and the pillars of our society became to honor outstanding scholarship in physics, to encourage interest in physics among students at all levels, to promote an attitude of service of its members toward their fellow students, colleagues, and the public, and to provide a fellowship of persons who have excelled in physics. As Sigma Pi Sigma grew, it strived to represent the living ideals and needs of our entire community.

As our understanding of the physical world and the structure of the universe has become more specialized, our need for cooperation and collaboration with each other is stronger than ever. After World War II, the explosion of students at American universities created new challenges and a wealth of opportunities for the honor society that ultimately resulted in the formation of the Society of Physics Students and its intrinsic linkage to the physics honors society. Today, the Society of Physics Students is a home to everyone with an interest in physics and astronomy, while Sigma Pi Sigma continues to honor excellence, service, and fellowship across the generations. It's the combination of societies that allows us to rely on each other more than ever to collaborate, communicate, and form the communities that will propel each other toward another 100 years of momentum. ●

Read Part 1:
www.sigmapisigma.org/sigmapisigma/radiations/spring/2019/reenergizing-sigma-pi-sigma-call-action

LEFT: Map of Sigma Pi Sigma chapters, reprint from page 24, September 1935, *Radiations*

ABOVE: Charter Members and Installing Party at the Upsilon Chapter, Wheaton College, June 3, 1931, reprinted from H. O. Taylor, A History of Wheaton College, December 1931, *Radiations*

BOTTOM: First known SPS/Sigma Pi Sigma student lounge at the University of Kentucky, reprinted from H. M. Sullivan, Sigma Pi Sigma Club Room at Lambda Chapter, December 1931, *Radiations*

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1. *Sigma Pi Sigma, the Physics Honors Society Information Booklet,* 3rd ed. (1946).
2. J. Pold and P. Mulvey, *Physics Bachelor's One Year After Degree* (College Park, MD: AIP Statistical Research Center, 2016), 3.
3. Marsh White, "Editorial: What's in a Name?" *Radiations of Sigma Pi Sigma* 1, no. 1 (Oct 1930): 20.
4. Video Interview of Sigma Pi Sigma icon March White, www.youtube.com/watch?v=4eyRu_QrRXg.
5. H. M. Sullivan, "Sigma Pi Sigma Club Chapter Room at Lambda Chapter," *Radiations of Sigma Pi Sigma* 1, no. 2 (Dec 1930).
6. Alphabetical Membership Directory, Sigma Pi Sigma Bulletin, *Radiations of Sigma Pi Sigma* 1, no. 1 (Oct 1930).
7. "Editor of the Radiations of Sigma Pi Sigma by Executive Committee," *Radiations of Sigma Pi Sigma* 8, no. 1 (Oct 1937): 53.

Feature

Six of the 2010s' Most Important **Physics Developments**

by Mikayla Cleaver, SPS Programs Coordinator

Detecting the "God Particle": July 4, 2012

In 1964, theoretical physicists predicted the existence of a particle we now call the Higgs boson. Its existence would help explain why particles—unlike photons—have mass. In 2012, scientists at CERN finally made the long-awaited observation of the elusive Higgs boson. The ATLAS and CMS collaborations independently detected a particle with Higgs-like properties using the Large Hadron Collider. As expected, the particle weighed in at 125 gigaelectronvolts. The confirmation came almost 50 years after its prediction, for which theorists François Englert and Peter Higgs were awarded the physics Nobel Prize in 2013. The experimental discovery of this particle is strong evidence for the existence of a Higgs field, which, in combination with the Higgs boson, "gives" other particles mass by transferring energy to them through a process known as the Higgs effect. This allows massive particles to interact gravitationally. Without it, particles would fly around freely at the speed of light and never interact.

First Discovery of Naturally Occurring Topological Insulators: 2013

Topological insulators are special materials that can conduct electricity on the surface but are insulating on the inside. These materials allow for the manipulation of electron spin and therefore have potential applications in "spintronic" devices that rely on electron spin instead of charge, as well as quantum computers that encode information in spin-based qubits instead of bits. They are a recent discovery, predicted in 1987 and synthesized for the first time in 2007. At that time it wasn't clear that naturally occurring topological insulators existed. But after kawazulite was found in a Czech goldmine and processed into nanoflakes in the lab, scientists at Germany's Max Planck Institute found that the mineral—made of bismuth, tellurium, selenium, and sulfur—behaves as a natural topological insulator. This is exciting not just because it is naturally occurring, but also because it may be a better candidate for some applications than synthetic topological materials due to its near-perfect crystal structure.

Gravitational Waves Shake Things Up: February 11, 2016

Einstein's theory of general relativity was corroborated once again when the LIGO and Virgo collaborations announced the first detection of gravitational waves. These ripples in space-time were detected on September 14, 2015, at the LIGO detectors in Livingston, Louisiana, and Hanford, Washington, and announced in February the following year. Scientists traced the source of the waves to the Southern Hemisphere. They were probably generated by the interaction of two black holes, estimated to be around 29 and 36 solar masses. The black holes likely circled each other, releasing energy through ripples in space-time before eventually collapsing into each other and releasing a tremendous amount of energy. This is the signal LIGO picked up. Scientists have since turned the signal into an audio recording, enabling you to "hear" the collision of the black holes. This work opens the world to a new form of observational astronomy through gravitational waves, helping to usher in the era of multimessenger astronomy—an approach that coordinates and integrates observational data collected by different types of instruments to create a more holistic picture.

In a 2017 illustration, NASA's Cassini spacecraft is depicted on one of its final orbits around Saturn. Image courtesy of NASA under Photo ID: PIA03883.

Cassini Space Probe Sends Its Last Message: September 15, 2017

The world said goodbye to the Cassini spacecraft as it plunged into Saturn's cloudy atmosphere in the fall of 2017, turning into a meteor from the high pressure and heat. Although it started with 6,900 pounds of fuel, Cassini crashed into Saturn with less than 90 pounds left. Over nearly 20 years, the spacecraft relayed important findings about Saturn and its surrounding moons to us here on Earth. Not only did Cassini discover six new moons, it also discovered hydrocarbon-containing lakes on Titan, water jets spraying from Enceladus, and the possibility of a large saltwater ocean under the ice of Enceladus. The water jets revealed the presence of hydrogen gas produced through chemical and thermal interactions, which on Earth creates an ideal environment for microbial life. Cassini was sent to its death to protect these potentially life-harboring moons from contamination, ensuring that the moons of Saturn will be a location of interest for scientists in the future.

Likely Source of High-Energy "Ghost Particles" Identified: July 12, 2018

Neutrinos are often called "ghost particles" because they are nearly massless particles with no charge and rarely interact with matter. There are millions of neutrinos passing through you every day. Most of the neutrinos scientists have detected are relatively low energy and are produced by the sun, supernovae, and collisions between cosmic rays and particles in the Earth's atmosphere. Astronomers have also detected a few surprisingly high-energy neutrinos from unknown sources. On September 22, 2017, the IceCube detector in Antarctica observed a neutrino with an energy of 300 trillion electronvolts. The project immediately asked multiple telescopes to look at the patch of sky where the neutrino came from to see if they could identify a likely source for the high-energy particle. Those observations suggest that the neutrino was produced in a galaxy four million light-years away, with a rapidly spinning supermassive black hole at the center—otherwise known as a "blazar." This collaborative effort is an amazing example of what is possible with multimessenger astronomy.

The First Picture of a Black Hole—Or at Least the Matter It's Ripping Apart: April 10, 2019

Captured by the Event Horizon Telescope, an array of eight ground-based radio telescopes around the world, the first-ever image of a black hole and its accretion disk shows the center of Messier 87, an elliptical galaxy 55 million light-years from Earth. The supermassive black hole located at the center, weighing in at 6.5 billion solar masses, casts a shadow on its surrounding accretion disk, shown in bright orange. Similar to how the sun bends nearby starlight during a solar eclipse, this image shows that there are objects massive enough to warp the fabric of space-time so that even light cannot escape. The image supports Einstein's theory of general relativity and also allowed scientists to measure the Schwarzschild radius of the black hole and calculate its mass. The result agreed with existing estimates from a more established method based on orbiting stars. This suggests that the image-based technique is a valid method of mass determination.

Honorable Mentions

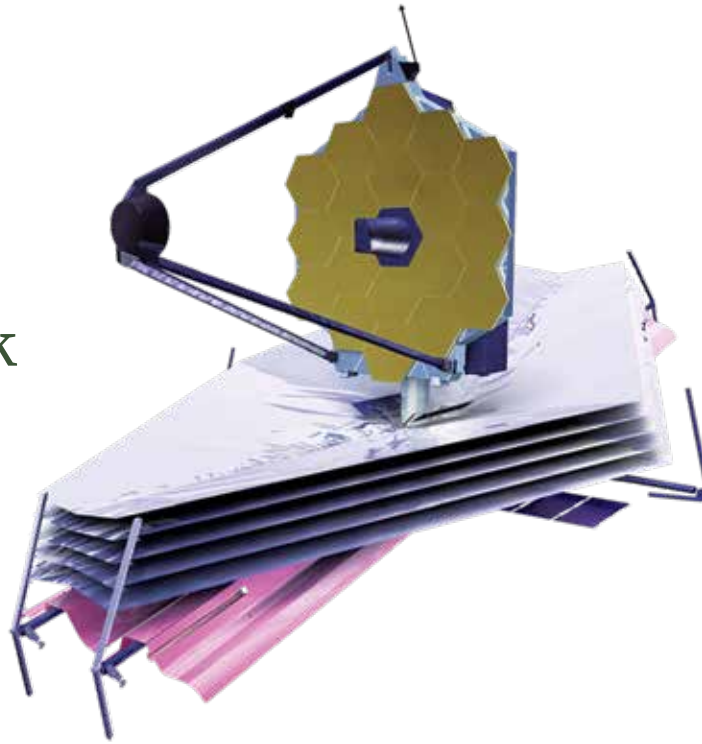
The past decade has been filled with innovative and important developments in physics and astronomy. Many not included in the above list still deserve to be mentioned. For example, in 2014, Aephraim Steinberg and his colleagues at the University of Toronto demonstrated that quantum information can be compressed. They were able to take the information stored in three identical quantum bits, or qubits, and represent it in two nonidentical qubits. This is an important step on the path to creating efficient quantum computers, because classical data compression methods don't work on quantum information.

In 2015, the successful landing and recovery of Falcon 9 flight 20 by SpaceX marked significant progress toward reusable rockets. It was the first time that the first stage of a multistage rocket successfully returned to Earth and landed upright. SpaceX went on to relaunch the first stage in March 2017 and expressed a goal of eventually reusing rockets more than once in 24 hours.

Finally, this decade delivered an exciting science experience for many people across America. On August 21, 2017, a total solar eclipse spanned the width of the entire continental United States—something that hadn't happened for 99 years. The path of totality crossed 14 states, and all parts of the country had views of at least partial totality. The next event of this kind will take place in April 2024, when the path of totality will cross 12 states. ●

Did we leave out any developments that you think were among the most noteworthy of the 2010s? Share your thoughts by emailing sps@aip.org.

Feature



The Man Who Helped Unlock Our Past Looks to the Future

by Will Ephlin, SPS Member, Kettering University

Before he won the 2006 Nobel Prize in Physics, before he was the project scientist for the James Webb Space Telescope, before he was listed as one of *Time* magazine's 100 Most Influential People in the World, and before he helped to provide irrefutable evidence that the big bang theory explains our universe's origin, something that Stephen Hawking called "the discovery of the century, if not all time"—before any of that—John C. Mather was just a curious young boy.

It was the 1950s in Upper Manhattan, and an adolescent Mather was taking in all he could at New York's Museum of Natural History. The walls were decorated with ancient dinosaur bones and long-dormant chunks of volcanic rock. On display for all to see were colossal fish skeletons, aligned so that the process of evolution was evident. It was a stunningly blatant message that nature is never done being discovered. That quest captivated Mather.

Today he's a world-renowned astrophysicist who has helped to explain one of the universe's most fundamental questions, but that memory of silently studying the hunks of rock and bone that adorn the museum's walls might be more important to him than any lecture or book.

Mather's father, Robert E. Mather, was a geneticist pursuing research in animal husbandry and statistics, specifically focusing on dairy cattle. As a boy, Mather remembers his father explaining the nature of living things to him. "I was about six, and a bedtime story one night was that living things are made from cells, and they have chromosomes in them, and they control what's going to happen. If you're six and you hear that story, you think, Well, of course it probably is like that....Pretty soon you say, That's really exciting, I want to know more.'"

This curiosity continued well into primary school and beyond. At the time, Mather couldn't name what it was that he wanted to do, but he knew that explaining the universe interested him. "It makes you think about everything around you, all the people around you, what different luck we all have ... It's all connected. We don't start at the same point, but we all change."

I sat down with Mather during the 2019 PhysCon in Providence, Rhode Island, to ask him about his past and present, and I was pleasantly surprised at how much he referenced the future. Throughout our interview, his eyes took me to distant galaxies and faraway planets, still full of the childlike wonder that captivates so many aspiring physicists.

SPS Reporter Will Ephlin (left) poses with Mather after the interview. Photo by Kendra Redmond.

Mather's achievements can be credited to years of careful research, but according to him, the origin of the project that would eventually earn him a Nobel Prize is something Mather refers to frequently when discussing the realm of science—pure luck. "I wandered around the physics department and asked professors what they had to work on; I had to find a thesis," Mather says. "So, these folks are going to work on measuring the big bang with cosmic microwave background radiation. Oh okay, I like that, can I work with you? And that's how it started."

I then asked Mather about the growth of modern technology. This is a topic that seems omnipresent in Mather's mind and was a key point of his plenary talk later that night. "I'm not scared, but I think bad stuff is happening already—you can see it. We are in an exponential growth phase of human society. Exponential growth doesn't continue forever." He says this with a calm acceptance. There are hazards and pitfalls along the path to prosperity, but Mather is comfortable accepting those. I ask him if he thinks this growth is good, and after a long pause, he responds, "You can't ask Pandora to put her box back...she won't."

LEFT: Rendering of the James Webb Space Telescope with its components fully deployed. Image courtesy of NASA.

RIGHT: Inside the American Museum of Natural History in New York, a place that inspired Mather's curiosity as a child. Photo by Aditya Vyas on Unsplash.

The past is an important keystone in Mather's viewpoint of the future, and he frequently references legends of scientific lore when discussing how to proceed on difficult projects. "People are storytelling creatures," he says, cracking a smile. "They remember what you tell them in stories much more than they will facts. So, give them stories."

When I asked him what stories inspired him as a youngster, I was surprised that they were tales of risk and peril. "The fact that Darwin and Galileo were persecuted for their discoveries, that made [science] important to me. [I realized] that opposition is a sign of importance," he says. This mindset has stayed with him. "When somebody [in] Congress says that they don't like [a scientific finding], it just proves how important it was that we did it, to me. So, we keep on going."

This type of inspirational, motivating point of view is what truly amazed me about Mather. He's reached the pinnacle of achievement in physics—he is a Nobel laureate, winner of the prestigious Robinson Prize in Cosmology, and the tip of the spear for NASA's latest and greatest extraplanetary satellite. Yet he shows humility, and above all else, the desire for his work to continue. To him it's not about awards or recognition. It's about making a better world, despite the challenges. Pandora's box may never close, but perhaps the act of opening it will help us find what we're looking for.

As we stand up to collect our things after the interview, Mather leaves me with truly profound advice. "Our job as scientists is to work on the unsolved problems. It's always terribly discouraging, because every day you work on the things you don't know about. Once in a while you solve something, but then it is immediately back to the part you don't know yet. So, you have to be tolerant of 'I don't know.' It's scary... but it's thrilling."

Feature

The Context of Scientific Progress: World War I and the Theory of General Relativity

by Kendra Redmond, Editor

In May of 1919, Arthur Stanley Eddington led an expedition to the West African island of Príncipe. It was a scientific expedition but not of Príncipe or its surroundings. The subject was Albert Einstein's theory of general relativity. The plan was to look upward from the strategically located island and capture the positions of stars near the sun during a solar eclipse.

Astronomers knew that starlight passing close to the sun would be deflected—the question was by how much. Newtonian gravity predicted one value and Einstein's recently developed theory of general relativity, another. Measuring the apparent positions of stars near the sun during an eclipse was a litmus test of a new and rather controversial field.

The expedition was successful despite the fact that "monkeys found the equipment fascinating, with lots of knobs to twiddle," Jocelyn Bell Burnell told 2019 Physics Congress attendees during a plenary talk on the subject. The test validated the theory of general relativity, and word spread quickly, boosting Einstein's notoriety.

But was that conclusion foregone? In her talk, Bell Burnell asked attendees to consider some of the ways that the stars had to align in order for this to be the outcome.

Einstein was living in his home country of Germany in 1915, the year he published the theory of general relativity. Eddington was English, living in Cambridge. At the time, British forces were actively fighting German forces, and England was characterized by anti-German attitudes, even within the scientific community. Luckily for Einstein, his 1915 paper landed on Eddington's desk.

"Eddington was interested in science, not Einstein's nationality," says Bell Burnell. Had Eddington been unwilling to read and support the work of a German, modern physics may have progressed much more slowly. Or had the stars been completely obscured by clouds that night in Príncipe. Or had the war not ended just in time to move forward with the expedition. Or had Eddington not been a great science communicator. Or had the world not been so desperate for good news that confirmation of Einstein's theory made newspaper headlines around the world. Or had the monkeys come out on top.

TOP: This image of the 1919 eclipse is the result of applying modern image processing techniques to a copy of a photographic plate made by Arthur Eddington and Andrew Crommelin. Visible is the solar corona, a giant prominence emerging from the Sun, and stars in the constellation of Taurus that were used to confirm general relativity's predictions. Image by ESO/Landessternwarte Heidelberg-Königstuhl/F. W. Dyson, A. S. Eddington, & C. Davidson.

In experiments and analysis, physicists control for outside influences at the highest standard. But political, societal, social, and financial conditions influence the path of scientific progress all along the way. There is no Faraday cage for politics or a vacuum chamber that keeps out financial considerations. For better or for worse.

Virginia Trimble, an astronomer and science historian at the University of California, Irvine, provides even more context on the events

Arthur Stanley Eddington (front, left) and Albert Einstein (back, left) pose with fellow physicists Hendrik Antoon Lorentz (front), Paul Ehrenfest (back, center), and Willem de Sitter at the Leiden Observatory in September 1923. Photo courtesy of AIP Emilio Segrè Visual Archives, Gift of Willem de Sitter.

TOP: Trimble presenting the 2019 Andrew Gemant Award prize lecture, "The Impact of World War I on the Sciences." To her right is a portrait of her by Richard Feynman. Photo courtesy of AIP.

BELOW: Experts suspect that Moseley, shown here circa 1910, may have received the 1916 Nobel Prize in Physics for his experimental work on the structure of atoms, were he not killed in action in 1915. Moseley volunteered for the Royal Engineers of the British Army during World War I and was killed during the Battle of Gallipoli, at age 27. Public domain.

leading up to this first test of general relativity in a class on how World War I (1914–18) impacted the sciences. During the war, many scientists, including Einstein, were going hungry due to low agricultural output, halted imports, and price controls. Work was interrupted as scientists became soldiers, and sometimes, as in the case of the exceptional English physicist Henry Moseley, they became casualties. The number of research publications decreased dramatically across the world, and once-thriving international scientific collaborations collapsed. "All science suffered greatly," she says.

But science has also benefited greatly from war.

Trimble notes that as men left for the battlefield, jobs in academia and industry were suddenly open to women—accelerating the pace with which women contributed to STEM fields and received the right to vote in many countries. Portable x-ray equipment, facial reconstruction, and prosthetics work advanced quickly, driven by attempts to keep soldiers alive and functioning. Developments in chemistry yielded new explosives and poisonous gases but also enabled the large-scale production of fertilizer, necessary to maintain food supplies even today. Infrared-sensitive photographic emulsions developed for reconnaissance formed the basis for astronomical advances. Sonar technologies developed to locate submarines have been adapted to map the seafloor and track biodiversity. "Nearly all technology advances come from war," Trimble says.

Trimble has turned her attention to the history of astronomy in recent years because of a natural curiosity but also because the past holds valuable context. "As many sages have said, Those who will not study history are doomed to repeat it. There is certainly some truth in that," Trimble says. The opposite is also true, she notes. "Things have unintended consequences. Knowing what's happened in the past can shed light both on how people react now and on what we might do now to avoid something that went badly in the past."

Reflecting on what lessons can be drawn from the story of Einstein and Eddington, Bell Burnell offered these thoughts to physics students. "It's always a good idea to try and make your own luck," she says. "Try and identify people of integrity, of honesty, and upstanding [character]. Those are the people you want to associate with." ●

Q&A with Virginia Trimble

Trimble as an mid-career astronomer.
Photo courtesy of American Association of Physics Teachers (AAPT), AIP Emilio Segrè Visual Archives.

Virginia Trimble is a professor in the physics and astronomy department at the University of California, Irvine. She studies the structure and evolution of stars, galaxies, and the universe and has published hundreds of papers, articles, and book chapters during her distinguished career. For 16 years she wrote a popular "year in review" article for the Astronomical Society of the Pacific based on a survey of all of the astrophysics papers published in 23 journals. In recent years she has been exploring several aspects of the history of astronomy. In 2019 she received the Andrew Gemant Award from the American Institute of Physics, which recognizes contributions to the cultural, artistic, and humanistic dimension of physics. Her responses to *Radiations* have been edited for length and clarity.

What strikes you about the difference between what students are learning today and what you learned when you studied astronomy?

It's not so much the content. Of course, the content has changed. There are new objects, new windows for observation, new technologies . . . and changes in fashion. When I first surveyed the field, more than half of the community worked on optical observations of stars. That's not true anymore; very few people work on stars. But I think the single thing that's changed the most is more. More people, more papers, more facilities. And the need to work in large groups. When I got my degree, the average paper had 1.2 authors. It now has 1.2 thousand or something like that. It requires a different kind of person. It requires a different set of skills.

What are some of the most fun things you've done during your career?

I really enjoyed that 16 years of writing a review of everything in astrophysics. That was fun to write because it gave me an excuse for reading everything and nobody ever tried to control what I said.

I wrote a piece for the *American Journal of Physics*[1] on the cluster of seven women who, in a fairly narrow period of time, came through Caltech astronomy and earned advanced degrees. There had been none before us, and it took another 20 years before there was another. We earned PhDs between 1964 and 1977. The article took forever to put together because I had to get the other six to agree on what we remembered from graduate school—which things were true, which were sort of half true, and which weren't true at all.

What advice do you give physics and astronomy students?

I try very hard not to give advice. Most of my experience is totally irrelevant. But there are some things that I think are important. One is that you should always be working on several different tasks at a given time so if you get stuck, you can go do something else. I don't mean multitasking—nobody does that well, and studies show that—but I do think having more than one task on your plate is a good choice. Attending conferences is very important, and taking notes. If you know a language besides English, don't lose it. It's another tool for understanding the world and communicating with people. Recently, I've started telling students to pay attention, because someday you'll be the only one who remembers.

1. Cohen, J., et al., "Uncle Jesse and The Seven 'Early Career' Ladies of the Night," *Am. J. Phys.* 87, 778 (2019); doi: 10.1119/1.5122880.

Physics:

by Kendra Redmond, Editor

As a physics undergraduate at MIT in the 1960s, Jearl Walker wasn't exposed to cutting-edge topics in physics. At least not in the classroom. He remembers sneaking into a seminar, listening in amazement as Johns Hopkins University's Riccardo Giacconi described his team's detection of the first extrasolar x-ray source in the universe. "I was really impressed by that, that there were still discoveries being made," Walker says.

Now a physics professor at Cleveland State University, Walker shares those mysteries with students in the classroom through his book *The Flying Circus of Physics* and by way of the physics curriculum. For the past 30 years, he's authored all of the new editions of the classic textbook *Fundamentals of Physics* by David Halliday and Robert Resnick.

The introductory physics curriculum hasn't changed much over the years. The core topics are tightly constrained, but Walker still strives to incorporate the latest discoveries into each successive edition, searching through some 200 journals for new developments that he can turn into examples.

In third-semester physics, when modern physics comes up, Walker packs in every new and exciting topic that will fit. Dark matter. The expansion of the universe. John Wheeler's delayed-choice experiment. He brings up all the mysteries that he "sure as heck hopes [physicists] solve before I die."

If instructors and textbook authors aren't careful, undergraduates can easily get the impression that everything in physics was figured out 200 years ago. But the topics that really capture the interest of students are the unknowns—the mysteries, according to Walker. "That's what excites students."

Those mysteries aren't static. As a *Radiations* reader, you know that the field of physics is constantly evolving. Existing mysteries are being solved, new mysteries are being discovered, and previous solutions are being modified all the time. But what does that mean for the next generation of physicists, and how are their experiences different from ours?

With this question in mind, we hope you enjoy this look back at recent developments in physics, presented relative to the educational milestones of the average class of 2020 physics graduate. ●

Notes:

- For simplicity, we assumed the average graduate is earning a physics bachelor's degree in four years and entered the program at age 18.
- New developments don't always happen at a defined moment. One could argue that some of these events should technically be attributed to a different year.
- It's not always clear who should be credited for a particular development. In this timeline, we've chosen to note the collaboration and/or the physicists commonly associated with that development, with the emphasis on the development itself.
- This is not an exhaustive list of important developments.
- Feel free to share your thoughts on this timeline with us at spsnational@aip.org.

1950s

Four decades before graduate is born

1952:
- Development of the first optical fiber (Kapany)

1953:
- Helical structure of DNA discovered (Franklin, Watson, Crick)
- First computer language developed (Hopper)
- First MASER developed (Townes, Gordon, Zieger)

1954:
- Construction on CERN begins
- First transistor radio (Texas Instruments)

1956:
- Discovery of the electron neutrino (Reines, Cowan)

1957:
- Launch of the first artificial satellite into orbit (Russia)
- Development of the theory of superconductivity (Bardeen, Cooper, Schrieffer)

1958:
- Invention of the integrated circuit (Kilby, Noyce)
- Defining paper on medical diagnostic ultrasound is published (Donald)

1990s

1990:
- Launch of the Hubble Space Telescope

1992:
- Arguably the first confirmed discovery of exoplanets (Wolszczan, Frail)
- First measurements of the cosmic microwave background radiation (COBE collaboration)

1995:
- Creation of the first Bose-Einstein condensate (Cornell, Wieman)
- Discovery of the top quark (CDF, D0 experiments at Fermilab)

1996:
- Work begins on the James Webb Space Telescope

1998:

Graduate is born

- First evidence that the expansion of the universe is accelerating (Supernova Cosmology Project team, High-Z team)
- Construction begins on the International Space Station

A Rapidly Evolving Field

1960s

Three decades before graduate is born

- Invention of the first laser (Townes)

1961:
- First time a person orbits the Earth (Gagarin)

1964:
- Quarks model proposed (Gell-Mann, Zweig)

1962:
- MOSFET invented (Hofstein, Heiman)

1965:
- Discovery of cosmic microwave background radiation (Penzias , Wilson)

1967:
- First discovery of a pulsar (Bell Burnell, Hewish)
- CT scanning is proposed (Hounsfield)
- Invention of the first handheld calculator (Kilby)

1969:
- First person on the moon (Armstrong)

2000s

2000:
- First crew resides on the International Space Station
- Optical Frequency Comb technique developed (Hall, Hansch)

2003:

Graduate starts kindergarten

- Space shuttle *Columbia* disintegrates during reentry, killing all seven crew members

2004:
- Graphene is rediscovered (Geim, Novoselov)

2006:
- Pluto is demoted

2007:
- Release of the first iPhone (Apple Inc)
- First synthesis of a topological instulator, in 2D (König and colleagues)

2008:
- First run of the Large Hadron Collider at CERN

2009:

Graduate enters middle school

1970s

Two decades before graduate is born

1970:
- First personal computer available for purchase (Blankenbaker)
- Black holes revealed as common features of general relativity (Hawking, Penrose)
- First CD-ROM patented (Russell)

1971:
- Invention of the floppy disc (Shugart)
- First patient brain scanned with CT

1972:
- First strong evidence for black holes (Bolton)

1973:
- Production of the first MRI images (Lauterbur)

1974:
- Discovery of the charmed quark (Richter and Ting)
- Development of the PET camera (Phelps)

1975:
- Invention of the first digital camera (Sasson)

1977:
- Discovery of the bottom quark (Fermilab)

2010s

2012:

Graduate enters high school

- Discovery of the Higgs boson (ATLAS, CMS collaborations)

2013:
- First Discovery of naturally occurring topological insulators (Gehring)

2016:

Graduate enters college

- First detection of gravitational waves (LIGO and Virgo collaborations)

2017:
- Cassini flies between Saturn and its rings in a "grand finale" ending

2019:
- First image of a black hole (Event Horizon Telescope)

1980s

One decade before graduate is born

1980:
- Quantum computing proposed (Feynman)

1981:
- Invention of the Scanning Tunneling Microscope (Binnig, Rohrer)

1984:
- First observations of the W and Z bosons (CERN)

1986:
- Space shuttle Challenger breaks apart shortly after launch, killing all seven crew members
- Invention of the atomic force microscope (Binnig, Quate, Gerber)
- First demonstration of optical tweezers (Ashkin)

1987:
- Topological insulators predicted (Pankratov)

1988:
- Discovery of Giant Magnetoresistance (Fert, Grunberg)

2020s

Graduate receives a physics bachelor's degree

Feature

Sharing the Spotlight: Resources for Correcting the Narrative of Physics History

by Hannah Pell, Research Assistant, American Institute of Physics Center for History of Physics

If I asked you to think of a famous physicist, who would come to mind? Newton or Einstein? Maxwell, Kepler, Bohr, Heisenberg, or Feynman? Physics curricula often recount the history of the discipline as the accomplishments of several individuals, as if their contributions built the science from the ground up.

But this story is incomplete. By focusing solely on the discoveries of a few, we overlook all of the physicists whose work inspired and informed the more famous discoveries. We also ignore the important role of collaboration and community in making scientific progress, and the fact that progress—and the historical record of progress—unfolds within social, historical, and cultural contexts. When we direct the spotlight only on the towering heroes of physics, we lose sight of the valuable contributions of so many others, especially scientists from groups that have traditionally been underrepresented in their fields.

As physicists, we can play an important role in changing the outdated narrative of our history—and of who physicists are and can be. One way to do this is by intentionally incorporating the stories of traditionally overlooked physicists into our classrooms, outreach events, and lectures.

The Center for History of Physics (CHP) at the American Institute of Physics has a collection of over 50 free teaching guides that use interactive and hands-on activities to highlight little-known scientists who have made invaluable contributions to physics and related sciences.

Written by SPS interns in collaboration with history of science graduate students, the teaching guides highlight the contributions of women, people of color, and LGBTQ+ figures in physics history. In many cases, their stories are told through oral history interviews, archival photographs, historical documents, and personal correspondence. Most of the guides are designed for high school classrooms, but the activities can be easily adapted for younger audiences, science outreach events, and community programs.

Incorporating often-ignored physics history in outreach events can help us correct misperceptions about physicists and portray a more accurate picture of how we arrived where we are today. Additionally, situating scientific discoveries within historical contexts emphasizes the dynamic interplay between physics and society. Lessons from history provide insight into the culture of physics, and by highlighting traditionally overshadowed figures in physics history we can cultivate a more equitable, supportive, and inclusive physics community today and in the future.

Here are a few examples of lessons that—quite literally—shine a light on physics history.

Spectra and Margaret Huggins

Margaret Huggins was a 19th-century astronomer who, alongside her husband, advanced spectroscopy as an analytical technique for identifying the chemical makeup of astronomical objects. In this lesson, students learn about Huggins and explore the emission spectra of different elements using diffraction glasses. They investigate how spectroscopy can be applied to astronomical objects and consider the status of 19th-century astronomy.

Portrait of Lady Margaret Lindsay Huggins wearing academic robes. Image courtesy of Science Photo Library.

Elmer Imes and Spectroscopy

Elmer Imes received a PhD in physics in 1918. He was only the second African American to receive a physics PhD, following Dr. Edward Bouchet in 1876. Imes made important contributions to the field of infrared spectroscopy, the study of how molecules absorb and emit infrared light. In this lesson, students learn about Imes's life and work while exploring how light refracts through a prism and how this relates to spectroscopy.

Portrait of Elmer Imes working in a laboratory. Image courtesy of the Fisk University Special Collections and Archives.

Victor Blanco in Chilean Skies

Victor Blanco was a Puerto Rician astrophysicist who navigated international politics to forge the way for observatories and research centers. He played a formative role in the Cerro-Tololo Inter-American Observatory, a United States observatory in Chile. Blanco's research focused on star classification and the Milky Way's structure. In this lesson, students discuss the relationship between science and politics, and practice identifying astronomical objects in a sky survey.

Victor Blanco at Kitt Peak National Laboratory in Tucson, Arizona, 1969. Image courtesy of AIP Emilio Segrè Visual Archives, John Irwin Slide Collection

All of the lesson plans are freely available on the Center for History of Physics website: www.aip.org/history-programs/physics-history/teaching-guides-women-minorities

Discoveries, Unintended Consequences, and the Values of Science

by Dwight E. Neuenschwander, Southern Nazarene University

> "It is a profound and necessary truth that the deep things in science are not found because they are useful; they are found because it was possible to find them."
> —J. Robert Oppenheimer

Hindsight is Always 20/20

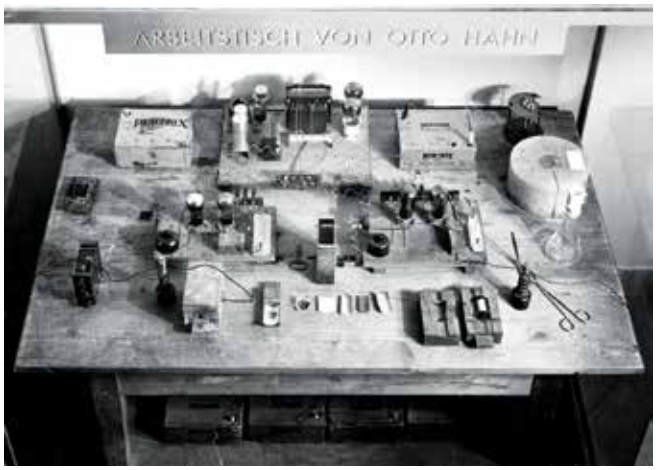
Life is strange: developments that initially seem good sometimes turn out to have disastrous consequences, and disasters sometimes have beneficial side effects. This observation about life is formalized by "learned historians" into a maxim called the law of unintended consequences. The journalist-historian Theodore White recalls examples such as the Civil Rights Act of 1963–64, "a beautiful piece of historic law-making." But, White recalls,

Of all the great events in domestic history since the war, the Law of Unintended Consequences might later claim this Kennedy legislation as one of its finest demonstration pieces. A new jurisprudence was opening up...[whereby] a law intended to unify would divide Americans by categories.[1]

Unintended consequences from physics discoveries and their applications are legion:

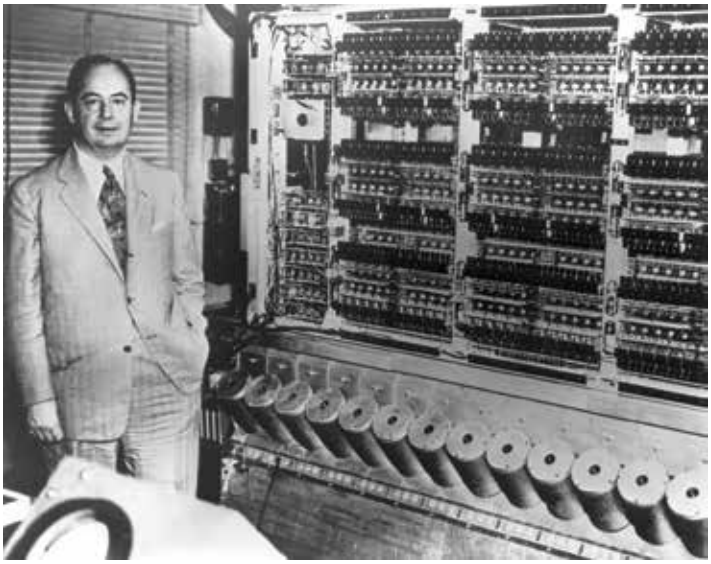
- The Industrial Revolution was never intended to send the planet down a path toward global warming and climate change.[2]
- When Marie Curie discovered polonium and gave radioactivity its name, no one immediately visualized nuclear waste or nuclear medicine.

Marie Curie in the laboratory. Image courtesy of the Curie Museum.



Otto Hahn's worktable used in the discovery of nuclear fission. Image courtesy of the Deutsches Museum Munchen.

- In December 1938 when Otto Hahn and Fritz Strassmann stumbled across nuclear fission and their data was correctly interpreted by Lise Meitner, they were merely trying to understand the nucleus. They did not intend weapons research. Nuclear fission was found because it was possible to find it.[3]
- When John von Neumann envisioned programmable computers facilitating weather predictions using complex meteorological models, I doubt that he intended the subsequent development of facial recognition algorithms that would enable a dictatorship to intimidate a population.
- I'm sure the internet founders never intended that instant access to information would result in the demise of deep reading.[4]
- Surely the college students who launched Facebook never intended for their creation to become a weaponized means for rendering suspect the notion of public "truth" or for foreign governments to disrupt national elections.
- Machines were originally intended to be tools for serving people. In his historical survey *Civilisation*, Kenneth Clark remarked that "in the world of action a few things are obvious....One of them



John von Neumann at the inauguration of 'IAS 1952.' Image courtesy of Nicholas A. Vonneuman

is our increasing reliance on machines. They have ceased to be tools and have begun to give us directions. And unfortunately machines, from the Maxim gun to the computer, are for the most part a means by which a minority can keep free men in subjection."[5]

Hindsight is always 20/20. The creators of something new almost always have good intentions. The law of unintended consequences, for good and for bad, inevitably applies. While we as scientists owe it to our fellow human beings to give our best to whatever we do, we are not society's saviors or censors. Although we must be part of the conversation, what society decides to do with our discoveries is society's business. Jacob Bronowski passionately argues this point:

Now the man who makes the discovery...must make the discovery even if his creation produces works which are rather ambivalent and can be used for one purpose or another. Society has to make some judgment about this, but I do not think the creator...should be a censor on behalf of society. Any man who discovered the destructive effects of atomic energy and withheld this discovery from mankind is in my opinion a maniac. And I use this word deliberately; he is a maniac because he has no notion of what can be made of the forces that he has discovered… for you to ask the scientist to keep a secret is just as bad as for him to go and give it to a foreign embassy. What business has he to decide what the nation wants to do with the knowledge which it possesses? This is not a subject for an individual's decision at all. He has no special competence in this.[6]

No one can judge Jacob Bronowski to be naïve about the unintended consequences of science on society. He was a member of a team that investigated damage inflicted on Nagasaki by the atomic bomb. Of that experience he wrote elsewhere,

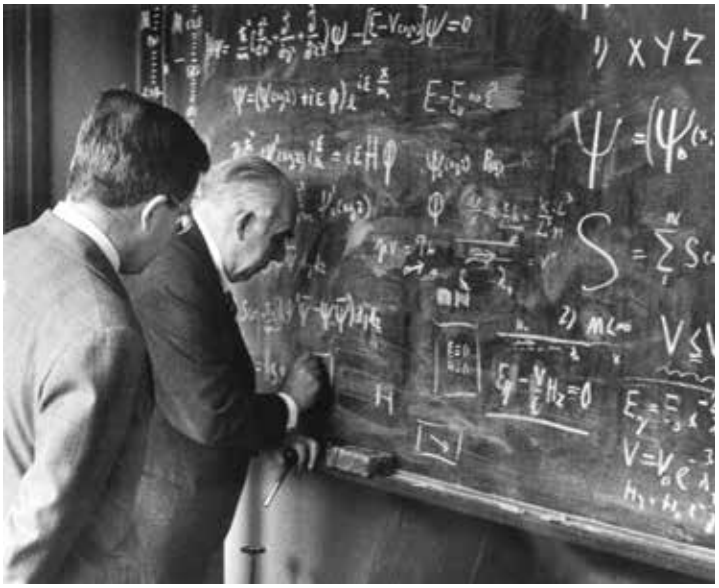
The power of science for good and for evil has troubled other minds than ours. We are not fumbling here with a new dilemma; our subject and our fears are as old as the tool-making civilizations. Men have been killed with weapons before now: what happened at Nagasaki was only more massive...Nothing happened in 1945 except that we changed the scale of our indifference to man.[7]

The dangerous unintended consequences of science say more about human nature than they do about science. Nevertheless, as scientists and science appreciators who are people of conscience, we seem to be caught in a dilemma.

The Values of Science

The *values* of science may be more important than the discoveries of science. Values are not imposed on scientists like the oath recited in a congressional swearing-in ceremony. They don't have to be, because those values are necessary conditions for doing science. Let us review some of them.

Respect for Doubt, Respect for Truth. Science can only be done with a robust commitment to both doubt and truth. Nature never lies, and if we would understand nature we must accept the answers she gives to the questions we put to her. Honesty between scientists is enforced through peer review and the replication of claims. But truth can be a slippery concept. Niels Bohr famously wrote that there are two kinds of truth: "simple truth" and "deep truth"—the opposite of a simple truth is false, but the opposite of a deep truth is also true.[8] Absolute truths are few; questioners who expect binary yes/no answers typically miss the point; existential questions seldom have universal answers. Nevertheless, the attitude is so widespread in popular culture today that evidence-based reasoning is indistinguishable from opinion (recall measles vaccination controversies and climate change denials) and the unthinking fearful acceptance that truth is whatever the latest demagogue du jour says it is are not only antithetical to the spirit of science but contain within them the seeds of their own undoing. Whatever else science may be, it is an obligation to doubt everything while acknowledging the reality of truth, even when we can only approach truth asymptotically. Some claims are so and others are not so, and we must recognize the difference and act accordingly. Ideology and wishful thinking do not negate nature's realities. As Richard Feynman reminded everyone, "Nature cannot be fooled."[9]



Niels Bohr (right) and son Aage Bohr (left) stand at a blackboard writing equations. Image courtesy of the AIP Emilio Segrè Visual Archives, Margrethe Bohr Collection

The hydraulic powerhouse of the Mitsubishi Steel and Arms Works in Nagasaki, 1,900 feet from the center of damage. Image courtesy of the AIP Emilio Segrè Visual Archives.

Living with Uncertainty. An essential boundary condition for respecting both doubt and truth is appreciating the limits of knowledge. In practice, science depends on measurement, and no measurement can be exact. And quantum mechanics teaches us that, in principle, the more precisely we know one observable the less precisely we can know a complementary observable. Scientists have learned to live with uncertainty as an integral part of doing science. Meanwhile, popular culture, as represented, for example, by whipped-up noisy crowds at political rallies, seems to expect simple black-and-white answers to infernally complex questions and expects those answers to be delivered with absolute certainty. Walter Kaufmann rightly observed that "certainty should not be purchased at the price of honesty."[10] Even though uncertainty is the price of doing science, we are not ignorant; when we know something, we know it to within such-and-such percent, an increment of tolerance.

Honorable Consideration of Alternatives. Before the cosmic background radiation was discovered, the steady state and the big bang were alternative cosmological models, and both were taken seriously. Although the steady state model was eventually ruled out by evidence, the existence of two models helped the proponents of both to think straight. Ideas that become obsolete are still honored as part of the scientific journey because they were tentative steps toward a deeper understanding. In science we give hearing to alternative hypotheses, not to show how open-minded we are but because the alternative may be right. But in the end the data decides, not our egos or desires or who can shout the loudest. And we still respect those with whom we disagree.

The proponents of the big bang and steady state models shared a common goal—the greater good of finding a genuine understanding of the universe. Such a shared vision seems to have been forgotten in modern society. Too often current public discourse proceeds as described by Jennifer Hecht: "There is a kind of mutual blindness, as if personal affiliation with one camp or another means more than does interest in the truth."[11] Anna Quindlen expressed her similar observations this way: "Today's graduates have also learned that having strongly held beliefs means expressing contempt for those of others."[12]

Change is inevitable, but when in the public arena a disruptive idea or technology is pushed by those with agendas that do not spring from a shared vision of the greater good, deliberate thought about consequences and alternatives can be drowned out by those with large marketing budgets or bully pulpits. Whenever a disruptive change is proposed, the question "What might be gained?" should be accompanied by the question "What will be displaced?" Unintended consequences need not include regret that we appreciate what we have only after it's gone.[13]

Dissent, Creativity, and Tolerance. Great discoveries in science occur because someone dared to challenge embedded assumptions. For dissent to be followed with the creativity needed to propose viable alternatives, the environment must, again, be one of tolerance. Bronowski continues:

I hold that you cannot carry out the activity of science if you do not have a society organized in this way: a society rich in dissent and yet rich in tolerance and rich in honor. I think that in this are the beginnings of principles which the scientist can teach the world at large.[14]

Doubt, uncertainty, honesty, dissent, creativity, respect, tolerance—these are values necessary for doing science. To the degree that they influence the wider society and civilization, we can avoid or manage some unpleasant unintended consequences and look to the future with optimism for the cause of human dignity. ●

References

[1] Theodore White, *In Search of History:* A Personal Adventure (New York: Harper & Row, 1978), pp. 304–306, 510–511.

[2] By comparing the rate of fossil fuel consumption to the rate of nature's production of hydrocarbons, the ecologist Jeffrey Dukes estimated humanity's rate of consumption exceeded the rate of nature's production by 1888. See Charles Day, "Running Out of Energy," *Physics Today* 1 (January 2020): 8. Day's editorial cites J. S. Dukes, *Clim.* Change 61 (2003): 31.

[3] Otto R. Frisch and John A. Wheeler, "The Discovery of Fission," *Physics Today* 20, no. 11 (1967): 43.

[4] Nicholas Carr, *The Shallows: What the Internet is Doing to Our Brains* (New York: Norton, 2011).

[5] Kenneth Clark, *Civilisation: A Personal View* (New York: Harper & Row, 1969), p. 346.

[6] Jacob Bronowski, *A Sense of the Future* (Cambridge, MA: MIT Press, 1977), pp. 19–20.

[7] Jacob Bronowski, *Science and Human Values* (New York: Harper Torchbooks, 1956 & 1965), p. 4.

[8] Niels Bohr, "Discussions with Einstein," in *Albert Einstein, Philosopher-Scientist*, Paul Schilpp, ed. (La Salle, IL: Open Court, 1949 & 1970), p. 240.

[9] Richard Feynman, *The Pleasure of Finding Things Out* (New York: Perseus Publishing, 1999), p. 169.

[10] Walter Kaufmann, *The Faith of a Heretic* (New York: Anchor Books, 1963), p. 36.

[11] Jennifer Hecht, *Doubt: A History* (New York: Harper, 2003), p. xii.

[12] Anna Quindlen, "Life of the Closed Mind," *Newsweek* (May 30, 2005): p. 82.

[13] One is reminded of Joni Mitchell's lyrics in "Big Yellow Taxi" (1970):

Don't it always seem to go
That you don't know what you've got
'Till it's gone.
They paved paradise
And put up a parking lot.

[14] J. Bronowski, Ref. 6, p. 20.

The Science Journalist
Emily Conover

Physics Reporter, *Science News*

"When I finally realized—more than a decade later—that I could combine the two interests into one career, I plunged into the field of science journalism."

When I decided that I didn't want to pursue a career in physics research, I went back to my roots. I had always enjoyed writing—starting with the detailed stories I wrote as a child. I first fell in love with physics thanks to popular science articles and books, and in high school I got hooked on the subject.

When I finally realized—more than a decade later—that I could combine the two interests into one career, I plunged into the field of science journalism. Now I report on the latest developments in physics research for the magazine *Science News*.

While earning my PhD in physics at the University of Chicago, I eventually reached a point where research in the lab wasn't fully satisfying me. I was studying neutrinos, a subject which I found fascinating. But the work I was doing helped answer only one question relevant to one subfield of physics. I was missing the bigger picture. Writing about physics allows me to keep abreast of the latest developments in all fields of physics research.

After completing my PhD and a few science writing internships, I ended up at the magazine *Science News*, aimed at the general public, particularly that segment of the population that relishes taking a deeper dive into research than can be found in newspapers. Founded in 1921, the magazine is published by the nonprofit Society for Science and the Public. I am the physics reporter on staff, and the other reporters for the magazine each cover different scientific beats.

My days are spent writing, scouring journals and press releases for important scientific developments, reading papers, and calling scientists on the phone to ask them questions about their research. I am lucky to work in a place where my editors respect my judgment and allow me to search out what I think are the most newsworthy topics.

For me, one plus to science writing is the rhythm: journalism demands short, regular deadlines. Rather than wrestling with projects that drag out endlessly and never feel quite finished, I complete most articles within a few days, and move on to the next thing. I get a sense of satisfaction each time I publish a story. Especially rewarding is when readers write in to ask questions or tell me they enjoyed learning about the subject.

LEFT: Emily Conover. Image courtesy of Science News.

RIGHT: Emily Conover holds an issue of Science News magazine. Photo courtesy of Emily Conover.

Despite leaving academia, I still feel that I'm contributing to the process of science. Journalists are independent sources of information—we aren't beholden to the scientists we interview. If a scientist's colleagues take a critical view of their research, I won't shy away from indicating that in the story. I try to lay out the debate so that readers can understand for themselves where scientific understanding lies.

Disentangling legitimate science from hype isn't an easy task for someone without a scientific background, so I aim to guide my readers through that quagmire. That's a service that I take pride in every day. ●

To catch up on your physics news, check out Conover's Science News page at **www.sciencenews.org/author/emily-conover**.

The Curator
Erin Brady

Planetarium and Physics Laboratory Manager, High Point University
Sigma Pi Sigma, High Point University, 2018

In my senior year of college, I knew academia wasn't for me. I have always been interested in finding new and impactful ways to share my understanding of science with the broader community, and I wanted to find a career path that would allow me to continue these efforts professionally. As an undergraduate at High Point University, I double majored in physics and studio art while simultaneously dedicating myself to science outreach. While this combination may seem unusual to some, it has set me up to do exactly what I want—explore new ways to share science with the community.

My passion lies in using art by which people can observe scientific information. Specifically, I'm interested in combining art and science to create visualizations that encourage people to think about science in a new way. By bringing together these seemingly disparate skill sets, I've created art pieces derived from the analysis of physics data from undergraduates! Each set includes two pieces that show the same data in two different ways: one as a relatively straightforward scientific approach to the data, and the second as an artistic portrayal of the actual data.

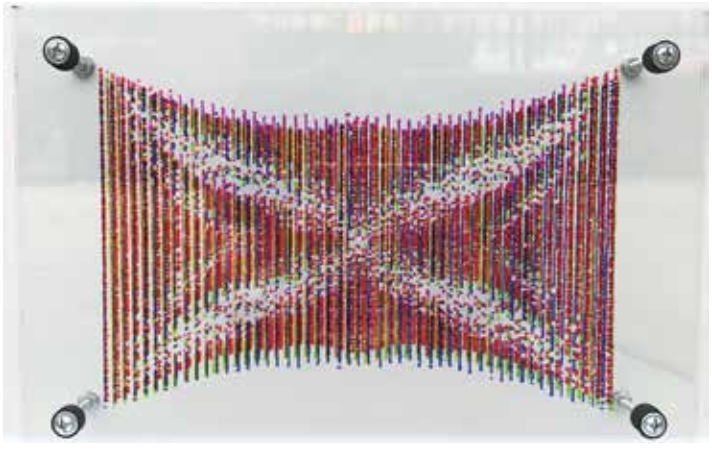
A recent example utilizes the data from my research on the Hofstadter butterfly. The first component is comprised of four pieces of glass, with each successive pane showing the butterfly graph with increased disorder. The artistic piece features four triangular origami shapes of paper—two larger pieces and two smaller pieces—arranged in the shape of a geometric butterfly. The origami pieces do not touch, and two are pulled farther outward to represent the increasing disorder in the system. This set is on display in the High Point University art department.

As the Planetarium and Physics Laboratory manager at High Point University, I find new ways to combine science and art to engage with general audiences. This role allows me to work with my three favorite things: physics, art, and outreach. I develop new content for the planetarium and share it with the campus community regularly by putting on shows and demonstrations. I engage with students, faculty, and staff during these shows, and coordinate visits with classes on campus. During this time, visitors experience science (astronomy, earth science, and biology) from a new perspective using the dome and are invited to consider new ways of understanding the world around them.

During a typical demo show, I take visitors on a tour of the universe, the Earth, and the human body using visualization software. I rotate the entire sky to see constellations all over the horizon and fly to another planet while stars zip past. My favorite software to demonstrate is ZygoteBody, which allows me to showcase many different physiological systems within the body. Highlighting one part of a system relative to the whole allows me to convey the interconnectedness and complexity of the body, and I am able to fulfill childhood dreams of hopping on a magic school bus and flying through the human body.

Our planetarium is still brand new, having opened only this past August. As the first person to hold this position, I get to find new ways to integrate other disciplines with the planetarium so that it's a space that extends beyond the sciences.

Physics careers exist beyond academia, and there is important work to be done in the field even when the word "physics" does not appear in the job title. To the next generation of physics students or anyone looking to make the next step in a career, I invite you to find what you are passionate about and encourage you not to be afraid to apply the skills, knowledge, and techniques you learned from physics in unconventional ways! ●



TOP: Erin Brady.

LEFT: Visualization of migration data from research on the Hofstadter butterfly.

RIGHT: Artistic representation of migration data from research on the Hofstadter butterfly. The origami pieces are pulled apart to represent the increasing disorder in the system. Line segments from disorder graphs are sewn into each triangular piece.

All images courtesy of Erin Brady.

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