APS News

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The Surprising Physics of How Dogs and Cats Drink

Yes, they lap. But what does that mean?

BY TARYN MACKINNEY

My dog, Lacey, is a messy drinker. Each time she laps, she shoots water out each side of her mouth, leaving puddles on the floor. The only evidence I have that some water makes it down her gullet is that she hasn't died.

Lacey's problem stems from a system bug shared by all canines. Dogs lack complete cheeks, that all-important feature that lets many animals, like horses and humans, close their mouths most of the way, creating a seal to suck up water. You can turn your mouth into a straw; dogs cannot.

Evolutionarily, going mostly cheekless makes sense for dogs, cats, and other predators. Without excess skin, they can bite and hold prey with more force, using even their back teeth. So, our carnivorous pets must lap instead of suck — but what that actually means was a mystery until a little over a decade ago.

It wasn't sloppy dogs that first caught scientists' eye — it was clean, posh cats. In 2010, researchers from MIT, Virginia Tech, and Princeton made an unusual discovery. Rather than using its tongue like a spoon to scoop water into its mouth, a cat flicks its tongue against the surface of the water and then yanks it back, dragging up a column of water with it. The cat closes its mouth around the top of the column, nipping off a little water, which the back of the cat's tongue shuffles along grooves on the top of the mouth. As the front of the tongue keeps lapping, those grooves act like a conveyor belt, pushing the water toward the throat.

The backwards "ladle" of a dog's tongue looks like it scoops water. It doesn't.

"The main feature they use during this lapping behavior is high acceleration," says physicist Sunghwan Jung, an author on the 2010 study who is now at Cornell Univer-

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The 40-Year-Old Gallery of Fluid Motion Goes Traveling

The famous gallery, showcasing the dazzling flows of gases and liquids, will appear in a National Academy of Sciences exhibit in DC this winter. Next year, it heads to Salt Lake City.

BY LIZ BOATMAN

A ripple in a pond, a burst of flame, a shapeshifting cloud: All abide by fluid dynamics, which describe the ways that liquids or gases flow. For Azar Panah, an associate professor of mechanical engineering at Penn State Berks, fluid dynamics is as much an art as a science.

"Whenever I show pictures of fluid visualizations to my family or friends, they're always so interested," she says.

Since 2021, Panah has coordinated the APS Division of Fluid Dynamic (DFD)'s Gallery of Fluid Motion contest. Scientists and students submit vibrant videos and posters, which are judged for their artistic and scientific value and originality. Winning entries are displayed at DFD's annual conference and online.

The gallery, launched in 1983, celebrates its 40th anniversary this year, and Panah — keen to expand its impact — is taking the gallery outside the conference. Starting this October, the works will appear as an exhibit in the National Academy of Sciences' cultural programs gallery

Milk splashes on a face. Credit: Azar Panah's PHOTO 321N course, Penn State Berks

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Peer Review is an Age-Old Practice, But Publishing is Changing

For Peer Review Week, Rachel Burley, APS Chief Publications Officer, reflects on the future of one of science's most vital processes.

BY TARYN MACKINNEY

Rachel Burley

The scholarly publishing industry is shifting at breakneck speed. Emerging technologies, like artificial intelligence, are upending academia and industry. Scientists are producing more papers than ever before.

But at its core, scholarly peer review — when researchers solicit and receive feedback on their papers from other experts — isn't all that different, says Rachel Burley, APS's Chief Publication Officer.

"Peer review has been around for many years," Burley says. "What it's all about, and why we do it, hasn't really changed. It's always been about ensuring the quality, validity, and reliability of research articles before they're published."

From Sept. 25 to 29, APS and myriad institutions and researchers are participating in Peer Review Week, a global event celebrating peer re-

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Physicists Fill in Wikipedia's Gaps on Climate Science

From solar cells to regional climate impacts, APS "Wiki Scientists" are making the science clearer, one page at a time.

CASSIDY VILLENEUVE

Boasting nearly 60 million pages and 18 billion monthly page views, Wikipedia is an information heavyweight, chock-full of what seems like everything. But look more closely, and the cracks show: Millions of pages have out-of-date or incomplete information, and many topics are missing entirely.

It's up to the public to make edits — and since 2019, physicists have stepped up to the plate. APS has trained 110 members, from high schoolers to a Nobel Prize laureate, to improve Wikipedia's coverage of physicists and their work, from scientists' biographies to explainers on quantum computing. These newly minted editors have practiced science writing on a global stage.

Now, they're filling gaps in content on climate change mitigation. For Allie Lau, a public engagement manager at APS, it made sense to focus a Wikipedia training on energy and climate science. "This is an area of importance to the Society and its members," Lau says.

The virtual trainings — six so far — let participants connect across disciplines and countries. By adding up-to-date climate research to Wikipedia, APS "Wiki Scientists," as they're called, are helping to fill major gaps in public understanding, including those outlined below.

A farmer tills soil on a Colorado farm where research on agrivoltaics — growing crops under solar panels — takes place. Credit: Werner Slocum / NREL

#1: Adding research on renewable energy technologies.

Nations are racing to invent, improve, and deploy technologies that slow or stop climate change. Technological progress happens quickly — and Morgaine Mandigo-Stoba, a physicist and Wiki Scientist, is trying to make sure Wikipedia keeps pace.

"Taking a topic that at its core is very technical, and making it useful and interesting to a broad audience like this, is a really fun challenge," she says.

Mandigo-Stoba recently expanded the article on thin-film solar cells, adding an array of useful details — what the cells are made of and how they work, for example. She even included a diagram of her own design. The page now attracts 5,000 readers each month.

"One thing we talked about in the [Wiki-editing] course is that people can feel a lot of anxiety around taking action against climate change," she says. "One way to alleviate that is to simply expose them to possible solutions. I hope that this page can help."

The article is one of several on renewable energies that Wiki Scientists have improved, including pages on solar and wind energy production. One participant added to a page on wind power, detailing the physics at work; the page gets 25,000 readers per month.

#2: Connecting climate change to daily life.

Climate change is on Americans' minds: 70% are alarmed, concerned, or cautious about it, according to recent research. But many struggle to understand the science and connect climate change with their own lives; even fewer know how to help.

This makes region-specific information vital. So when APS member Maggie Geppert stumbled on the Wikipedia page on climate change in Illinois, she immediately spotted issues, and a chance to help. "It was in bad shape," Geppert. "It was a series of long quotes from a single source from 2016."

Improving the page felt personal. "It's about where I live," she says. "My students will be able to read it and relate to the places and climate conditions it describes."

She added all-new information, from projected climate change ef-

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How Searching for the Higgs Prepared this Physicist to be an AI Leader in the Corporate World

For Sarah Schlobohm, a physics degree led naturally to machine learning.

BY KENDRA REDMOND

A PhD in particle physics should come with a free programming degree, says Sarah Schlobohm.

As a graduate student working on Fermilab's DZero experiment, a precursor to the ATLAS and CMS experiments that discovered the Higgs boson, Schlobohm spent many long days running algorithms on complicated data. At first, she didn't know she was using machine learning — she was just doing research. Now she spends her days using machine learning and artificial intelligence (AI) to address challenges in the corporate world.

The move from analyzing particle interactions to business transactions wasn't much of a stretch for Schlobohm. "You're pointed at some slightly different data, but a lot of the techniques, a lot of the processes, are still the same," she says. That includes specific models and algorithms and a scientific approach to solving problems.

But it wasn't the route she initially expected to take. As a new doctoral student, Schlobohm imagined herself becoming a physics professor — the stereotypical path. But as her thesis neared completion, she realized that there were far from enough academic positions for all the graduate students who wanted one. So, like many of her peers in particle physics, she started exploring jobs in data science.

"I was nervous about leaving science," Schlobohm recalls. "Would I be able to take this [physics education] anywhere?" The answer, she found, was a resounding yes. The skills and techniques students learn throughout a physics education are transferable — and valued — outside of academia.

Now, she's all about AI. Machine learning and AI have a lot to offer the business world, according to Schlobohm. And the opportunities have only grown with the advent of generative AI — which can create new content or code — and its newfound accessibility.

"We're in this AI moment," Schlobohm says. She recalls when the internet became a reality, and then Google. "That's what this feels like. We don't know what's going to happen yet, but it's going to be big." Schlobohm expects to see many breakthroughs in the next few years, but it's already clear that generative AI models can code, debug, and process information much faster than traditional methods. That makes it excellent for addressing efficiency problems, she says.

For example, imagine that a bank has detected fraud perpetrated by a business owner. Now it wants to know whether the fraud extends to associated businesses, and if so, how. Traditional investigative methods can be time-consuming, but using AI, investigators can map the fraudster's relationships with people at linked companies and more quickly identify people of interest.

Much of Schlobohm's career has involved using machine learning and AI in the financial sector: auditing financials models, assessing credit risk, detecting fraud, and using data science to prevent crimes like money laundering and terrorist financing.

Most recently, Schlobohm was head of AI at a global technology consulting company that works with businesses across sectors, from healthcare to green technology. Her next move is into the human resources space at a company called the Citation Group, where she'll be working for — believe it or not — a PhD geophysicist.

"I work with a lot of physicists," says Schlobohm. "I've hired some physicists, in part because I know what the training is." That training includes problem solving and data analysis, but valuable soft skills, too, like the ability to ask good questions

Sarah Schlobohm continued on page 4

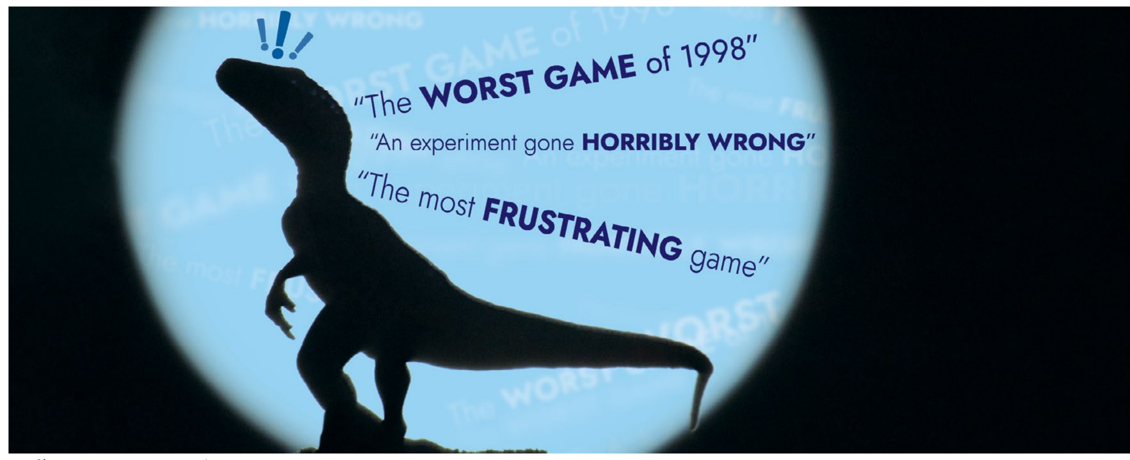
Sarah Schlobohm, a physicist turned data scientist, works in AI — and has fun with it, too. (These images of Schlobohm were generated by the AI-based app Retrato.) *Credit: Images created by Retrato / provided by Sarah Schlobohm*

THIS MONTH IN PHYSICS HISTORY

October 1998: Trespasser Makes History as the First Video Game to Incorporate a Complete "Physics Engine" — and Flops

The *Jurassic Park*-themed game was the first to use code that crunches mechanics equations with lightning speed. The game was trailblazing, and its glitches disastrous.

BY LIZ BOATMAN



Credit: Courtney Howerton / APS

The video game *Trespasser*, released in 1998, was promised by its developers to be revolutionary. Packed with visually dazzling dinosaurs and detailed sets, it paved the way for major advances in the "physics engine," or the equation-crunching code that governs how objects interact in video games. It was, perhaps, one of history's most daring feats of game development.

It also was one of history's biggest video game flops.

In 1993, Steven Spielberg's 1993 film *Jurassic Park* wowed audiences around the world with its realistic dinosaurs, who are brought back from extinction to tromp around a theme park on a fictional island. When the operation suffers a meltdown, dino mayhem ensues. The 1997 sequel, *The Lost World*, is set on a nearby island. (More mayhem.)

After the first film's release, DreamWorks Interactive scrambled to create a cutting-edge, single-player video game, slated to launch in late 1997, whose storyline would take place a year after *The Lost World*'s plot. In the game, *Trespasser*, players control Anne, who becomes stranded on one of the dinosaur-ridden islands after a plane crash.

Despite developers' grandiose promises, the game faced tremendous challenges, running over budget and schedule. When the game finally hit shelves a year late, the hype backfired. One reviewer branded *Trespasser* "an experiment gone horribly wrong." Another described it as "the most frustrating game I have ever played … filled with boring gameplay and annoying bugs."

Only 50,000 copies sold. By comparison, *Duck Hunt*, the 1984 game in which the player shoots at ducks while a bird dog mocks every miss, sold over 28 million copies. Minecraft has surpassed 238 million installations.

But *Trespasser* was the first video game to rely exclusively on classical mechanics — impulse, force of gravity, and multi-body collisions, for example — to govern motion and interaction during game play, by using a fully-fledged "physics engine" in its software. It was also the first game to incorporate "ragdoll physics," in which a body is treated as a group of rigid shapes connected by joints on which gravity can act, like in real life. (Imagine a velociraptor you've killed *tumbling* down a hillside, instead of bouncing like a ball or falling over.)

Until the mid-1990s, most games were simpler, 2D side-scrolling games, like *Super Mario Bros.* But in 1996, *Super Mario 64* saw enormous success with a 3D game environment, and other developers raced to follow suit. In 1997, a year before *Trespasser*'s release, developers released a James Bond-themed video game called *GoldenEye 007*. Although the game was designed mostly in shades of gray to speed up visual rendering, it had impressive 3D programming and was a commercial hit.

But *GoldenEye 007* lacked a fully developed physics engine. Without this, certain actions, like death scenes, followed prescribed sequences. Each kill looked like the next. By contrast, *Trespasser*'s developers sought to build the most advanced physics engine ever — and that meant they had to *develop* the ragdoll physics, among other kinematic elements.

"Kinematic simulation was the core of what they were doing in *Trespasser*," says computer science professor Seth Berrier, who teaches video game design at the University of Wisconsin-Stout. "The fact that they could just turn the ragdoll physics on and let the physics happen, that would have been a really big leap at the time."

All those firsts are also the reason *Trespasser* flopped. "*Trespasser* was a victim of its own greatness," says Berrier. "They discovered something way ahead of its time."

Trespasser *was the first video game to use a fully-fledged "physics engine" in its software. It didn't go quite to plan.* *Credit: Still shot from* Trespasser *(DreamWorks Interactive), uploaded by Phil Iwaniuk to TechRadar.com.*

Back in 1997, the average home computer had at most 32 MB of RAM, or short-term memory, crucial to running a game. Today, a typical laptop has 64 GB of RAM — 1,000 times more. Processor speeds have increased, too, from about 300 MHz in the late 1990s to more than 3 GHz today. Combined, that's thousands more physics calculations a computer can churn through in a single second.

The biggest advance, though, was the GPU, a separate processor just for graphics. "While it's called the graphics processing unit, it's really just a linear algebra engine. You can use it to do any problem that reduces to a system of equations," says Berrier. "Physics simulation was one of the earliest non-graphics applications of the GPU."

Because most home computers didn't have top-notch GPUs in 1998,

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It's Tough to Teach Computation in Advanced Physics Labs — So Physicists Workshopped It

In June, 12 faculty gathered at a Reichert Foundation workshop to brainstorm computation-based modules that instructors can incorporate into advanced labs.

BY LIZ BOATMAN

Hana Dobrovolny, physics chair at Texas Christian University (TCU) in Fort Worth, inherited her department's advanced lab course in 2015. She knew she needed to introduce new labs that catered to biophysics and astronomy majors — easy enough. But incorporating computational work into the experiment-heavy course proved trickier.

"It's going to be important for students to have good computational skills," says Dobrovolny, and to understand the limitations of computers in physics careers. But while she was quick to identify more modern themes for the new labs, she still struggled to tie in computation.

Part of the problem is time. "The curriculum is, in part, a zero-sum game," says David Van Baak, a former physics professor at Calvin College in Michigan, who frequently designed new setups for advanced labs. "There are only so many weeks in the semester, and anything you want to put in comes at the cost of needing to eject something else."

Many advanced lab instructors are also isolated. In most physics departments, only one faculty member teaches advanced lab, making it difficult for instructors like Dobrovolny to work with colleagues to develop and implement innovative ideas.

Emeritus physics professor Jonathan Reichert, who founded the J.F. Reichert Foundation and co-founded TeachSpin, both dedicated to designing advanced physics labs for instruction, had been thinking for years about the challenge of integrating computation and experiment.

ICEP workshop participants explore a lab teaching tool, the TeachSpin innovation studio. Credit: Matt Lohr

"[Reichert thought] maybe there was a natural overlap — a natural set of experiments and computations which could inform each other" to benefit advanced labs, says Van Baak, now TeachSpin's lead physicist.

Reichert floated the idea of a workshop to the foundation's board, and the idea stuck. The Integration of Computational and Experimental Physics (ICEP) workshop was held in Buffalo, New York, in June 2023, sponsored by Reichert's foundation.

The goal of the workshop was to bring computational and experimental physics faculty together — experts from "both sides of the aisle," says Van Baak — to re-envision the advanced lab experience for today's students, who need to learn workforce-ready skills.

When Dobrovolny saw an advertisement for ICEP in her inbox, she jumped at the chance to apply. She and 11 other faculty attended, traveling from schools across the United States.

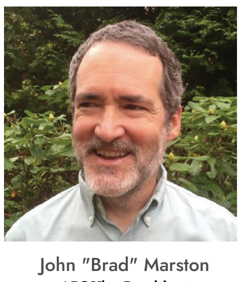
Van Baak kicked off the three-day event by having each attendee give a 10-minute presentation on a topic of their choice. "We got talks of very different character," he says. "Some started from computation, some started from curriculum, some started from educational theory, some started from apparatus or software." In turn, the presentations jump-started conversations and working groups about the upper-level physics experience.

One presenter laid out a three-circle Venn diagram — theory, computation, and experiment — and plotted standard courses, like optics and advanced lab, in it. The group was surprised to see that "there are very few things that naturally populate all three circles," Van Baak says. "In other words, there are very few experiences students encounter that really show that there's this three-legged support for the enterprise of

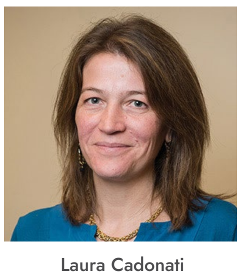
ICEP workshop continued on page 4

APS Announces Results of 2023 Election

APS is pleased to announce the results of the 2023 General Election. Congratulations to our newly elected leaders! All terms begin on Jan. 1, 2024. Learn more at go.aps.org/election.



John "Brad" Marston
APS Vice President



Laura Cadonati
APS General Councilor

Luisa Cifarelli
APS International Councilor

Nan Phinney
APS Nominating Committee Chair-Elect

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sity. "So their acceleration should of course be more than G, gravity, to withdraw the water."

In other words, a cat "exploits fluid inertia to defeat gravity" — so gushes the 2010 paper.

But the team still thought dogs scooped water. After all, a dog's tongue curls backward into a ladle shape as it laps, and in slow-motion videos, you can spot liquid in the cup of the tongue. Case closed!

Until the next year, when Harvard researchers X-rayed dogs drinking and realized that they were doing what cats did — albeit in a messier way. "We conclude that cats and dogs share the same basic mechanism," they wrote. "Liquid adheres to the dorsal surface of the backwardly curled tongue tip."

What about the water the dog scoops into its backwards ladle? That water ends up underneath the dog's tongue — a problem for pooches, since water must be above the tongue to be swallowed. "For humans, if you have water underneath your tongue, you can close your mouth and just push the water above your tongue," Jung says. Not so for cheekless dogs — that water simply dribbles out.

So why do dogs bother to curl their tongues at all? In 2015, researchers at Purdue University and Virginia Tech, including Jung, took a closer look. They filmed 19 dogs drinking, from a Yorkshire Terrier mix to a Great Dane, and modeled their drinking using rounded glass rods.

The team realized dogs' curled tongues let them drink more water. "If you have a bigger object pulling out of the water, then a large column of water is formed, [and] if you want to make a bigger structure, you're going to curve your tongue and make a very round shape," says Jung.

In other words, a dog's curled tongue becomes a kind of piston, which punches the water with a larger area, pulling more water into the mouth. The dog closes its mouth around the top of the water column at just the right time to maximize the amount of liquid — 1 or 2 milliliters per lap, the team found.

There's another difference between dogs and cats. "With the cat, you're going to see a little deceleration just before they pull their tongue [into] the mouth," says Jung. "But if you look at the dog, they maintain their acceleration for a longer time." A bigger, faster-moving piston makes for a bigger mess.

Jung isn't sure why dogs and cats do things a little differently. "Maybe it's due to the nature of the animal," he says. "The cats, they hate water."

With dogs and cats figured out, Jung — one of a growing number of physicists studying the living world — has turned to a more unusual critter. "We're looking at the drinking behavior of bats," Jung says. Less adorable, admittedly, but the physics might be just as weird.

Taryn MacKinney is the Editor of APS News.

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in Washington, DC. (DFD's meeting is in DC in November.)

To design the exhibit, Panah turned to APS's Joint Network for Informal Physics Education and Research (JNIPER), a community for people designing, facilitating, or studying informal physics learning activities. Registration is free, and APS membership is not required to join.

The network just wrapped up a four-part workshop series aimed at helping people like Panah design engagement activities.

"The workshop has been eye-opening for me," says Panah. "I do some sort of evaluation in my courses in traditional classrooms, but I've never done in-depth assessment and evaluation for outreach activities in museums before."

The workshop offered a helpful structure "to first figure out who your audience is, what your main goals are, what kind of activities you would like to design for them, how you are going to assess those activities, and how you can improve your efforts," she says.

Through the JNIPER workshop, Panah saw an opportunity to engage undergraduates from Penn State Berks who will be volunteering in the gallery's exhibit during the DFD meeting, by crafting their experience as volunteers to help build their identities as scientists.

The exhibit, which will be open to the public from Oct. 2, 2023, through Feb. 23, 2024, will feature still images, sculptures, and a wrap-around projection installation with videography.

"I'm working with two professional curators, Natalia Almonte and Nicole Economides, who have designed this beautiful space for us," she says.

Next year, when the DFD meeting is held in Salt Lake City, the gallery will travel there. A new installation will be developed to connect with the public in Utah.

Panah's interest in fluid dynamics started when she was young. She studied aerospace engineering as

Incense smoke rising into the air. Credit: Azar Panah's PHOTO 321N course, Penn State Berks

an undergrad, and her doctoral research focused on the aerodynamics of flapping wings in nature. "It was mesmerizing, but I wanted to understand the physics as well," she says.

She thinks the Gallery of Fluid Motion can inspire in others what her education inspired in her — an interest in fluid dynamics. "You may not know the science behind the patterns while stirring milk into coffee," but observing them "raises the question in your head," she says. That curiosity can inspire passion, possibly — hopefully — in fluid dynamics.

The Gallery is one of several creative approaches that DFD members are taking to share fluid dynamics with the public. This winter, another DFD group is planning to publish two anthologies of creative nonfiction aimed at inspiring girls and women to pursue careers in the field.

Both efforts act as invitations. "The more people you have in the field, the more perspectives you get," says Panah.

Even if gallery visitors aren't inspired to become physicists, Panah feels optimistic. The gallery could, after all, "change someone's opinion about science or art."

Visit the Gallery of Fluid Motion from Oct. 2, 2023, to Feb. 23, 2024, in the Upstairs Gallery of the National Academies building at 2101 Constitution Avenue NW in Washington, DC. Anyone with a government-issued photo ID can visit weekdays between 9 a.m. and 5 p.m. Admission is free.

Liz Boatman is a staff writer for APS News.

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fects, like frequent flooding and harmful algal blooms, to current mitigation efforts in Illinois, like a job-training program for workers transitioning to renewable energy.

Current efforts felt like an especially important piece of the story. "[Climate change is] really, really big and really, really hard, but there are people who are willing to take action now," says.

#3: Introducing the public to real scientists.

A Wikipedia biography recognizes a scientist in real time, boosting her credibility, changing stereotypes about what scientists look like, and building trust in research. This is especially important for scientists in politicized fields, like those who study climate.

By writing these biographies, Wiki Scientists put faces to climate research. For example, editors have updated profiles for Ayana Elizabeth Johnson, Katharine Hayhoe, and Kate Marvel, showcasing their contributions for thousands of readers every day.

For many of these editors, getting started felt hard, but the work paid dividends. "Once you get over the fear of editing something which potentially will be read by many people, editing Wikipedia is not that difficult," one APS Wiki Scientist noted. "And the benefit is that you are making real contributions to pages that are read by many."

And the Wiki course is a chance to connect. "This class was an opportunity for me to mix with physicists in all different places around the world, at many different stages in their career," Geppert says. "It was a lot of fun."

Cassidy Villeneuve is a technical writer and climate interpreter based in Chicago.

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physics" — a challenge for Dobrovolny, an experimentalist turned theoretical physicist, as she redesigned TCU's advanced lab course.

Dobrovolny says TCU's upper-level physics courses used to look a lot like the traditional curriculum still followed at many schools. "In advanced physics courses, it's often separated as 'these are lecture classes where you learn the theory' and then 'these are advanced lab classes where you get to play with stuff.'"

> "It's often separated as 'these are lecture classes where you learn the theory' and then 'these are advanced lab classes where you get to play with stuff,'" says Dobrovolny. "But that's not really how it works when you get into research."

"But that's not really how it works when you get into research," she says. "Even if you are primarily a theorist, you really do have to understand how the machines work, and what they're measuring, in order to model your system correctly. And vice versa — experimentalists need to understand the models so they can design experiments that can validate or disprove them."

The workshop helped her realize that "the whole way physics education is done should be rethought," she says. "We shouldn't have *just* lecture classes and *just* lab classes."

She now has concrete ideas for new labs. And with support from other workshop participants, she plans to add computation to the existing nonlinear circuits lab in TCU's advanced lab course. "It's pretty easy to write down the equations for the circuit, and then you can have the students run those on the computer, and then hopefully they can get the real circuit to match," she says.

Van Baak is excited to see how the ICEP participants will use ideas from the workshop, including "drop-in modules," or fully developed short units combining computation with experimental work, which the participants conceived of as a way to support instructors like Dobrovolny.

Meanwhile, Dobrovolny hopes participants stay connected. "It was really nice to have other people with a similar mindset to bounce ideas off."

Liz Boatman is a staff writer for APS News.

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and communicate technical information to nonspecialists.

In generative AI, your output depends on the model, its training, and the question you ask. "You have to think deeply about what problem you're trying to solve and how," Schlobohm says. And asking the right questions is so important that it has its own buzzword in AI: prompt engineering.

"Good prompt engineering is how you get generative AI to give you a good answer," Scholobohm says. "But that's just another way of saying 'ask a good question.'" She credits her science with teaching her what 'good' means, and she appreciates that any physicist she hires has that knowledge.

Physics students often develop the second soft skill Scholobohm credits for her success — communication — during extracurricular science outreach activities. Outreach experience "is so valuable in a business setting," she says. "That ability to translate the technical to people who are clever, but not technical, and especially not technical in that area, has been so important," Scholobohm says.

The business world has a different culture than physics; you have to interact with clients, dress nicely, and be polite, according to Scholobohm — even when someone asks an off-the-wall question. "When someone comes up to you and says, 'So does this mean we're like, all really made of energy?' You have to figure out how to answer that question accurately, but tactfully. It turns out that is super important in business and a lot of different areas."

Schlobohm also regularly contributes to discussions about AI and ethics, giving talks about maintaining data integrity, overcoming biases in training data, and guarding against privacy leaks. She's active in educating the next generation of data scientists by developing training modules, mentoring others, and talking at career events.

Behind it all is curiosity about how the world works. "I love thinking about new ideas," Schlobohm says. "What if we take this idea and push it to its furthest possible limit?"

Kendra Redmond is a writer based in Minnesota.

As the Congressional Science Fellowship Turns 50, Former Fellows Reflect on Their Experience — and Where They Are Now

BY TAWANDA W. JOHNSON

Well-informed federal policy relies on science, a fact that physicists — like those who shaped nuclear policy after World War II — have known for decades. Fifty years ago, APS helped found an initiative to involve more young scientists in policymaking: the Congressional Science Fellowship.

Elaine Ulrich, Reba Bandyopadhyay, and Anna Quider.

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

It's not just Congress that benefits: The experience jumpstarts many fellows' careers.

Elaine Ulrich, CSF class of 2008-09, is now a senior advisor for the Department of Energy's Office of Cybersecurity, Energy Security, and Emergency Response. "[I work] with many scientists and engineers, analysts, entrepreneurs and communities on a whole range of issues related to clean energy," she says.

During her fellowship, Ulrich honed her skills in communicating her work to people who might not have scientific backgrounds, "making it accessible and helping people to understand the 'why' behind the innovation and analyses," she says. And it was her fellowship that inspired her to pursue a career in public service.

For Reba Bandyopadhyay — a legislative and policy analyst at the National Science Foundation and deputy executive director of President Biden's science and technology council — her 2014-15 fellowship helped her learn to write concisely, able to whittle down a big issue into one page. "For impactful writing in policy, the bottom line should be up front," said Bandyopadhyay. "State the problem or goal, and then the proposed actions to address the problem or achieve the goal."

The fellowship was also a boon for her professionally. "I was able to launch a new phase of my career, moving into senior positions in federal policy," she says — moves she attributes in part to the policymaking knowledge she gained.

Anna Quider, founder and principal of The Quider Group, LLC, a strategic consulting and speaking business, says her 2011-12 fellowship helped her build resilience.

"I heard from constituents and organizations across the ideological and political spectrum," she says. "Some people and organizations cheered the work I was doing, and some disparaged it. I had to learn to roll with their feedback and not take it personally."

Another lesson Quider learned during her fellowship: "Don't let perfect be the enemy of good," she says. "I thought I'd learned that lesson from astrophysics research — we've all had that paper we endlessly tweak — but it has a whole new meaning when applied to policymaking."

Like Ulrich and Bandyopadhyay, Quider's fellowship solidified her interest in federal science policy. It also inspired her to get more involved in the physics community. "For example, I am this year's chair-elect of the APS Forum on Physics and Society," she says.

And the connections she made have endured. "The people I met through this fellowship have served as mentors and sponsors for me throughout my career," she says.

Applications for the next class of fellows will be open from Sept. 1 to Dec. 1, 2023. To learn more, visit the APS Congressional Science Fellowship site.

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

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gamers encountered pixelated imagery and glitchy gameplay in *Trespasser*, made worse by coding bugs in the game's physics engine.

Some of the glitches were comical. For example, any fan of *Jurassic Park* knows that some of the film's scariest moments occur when characters meet velociraptors indoors. But the game's designers couldn't put dinosaurs inside buildings because *they would get stuck in the walls*.

In one strange glitch in Trespasser, *dinosaurs became stuck in walls.* Credit: Still shot from Trespasser (DreamWorks Interactive) uploaded by Alan Chan to mobygames.com.

This bug stemmed from a timestep — the time interval between successive iterations of the motion in a scene — that was too large, a necessary measure to reduce computational costs. In a game, the player sees the graphical rendering of an object; what they don't see is a less refined, invisible "box" that contains and moves with it. When the box penetrates another object's box, a "penalty force algorithm" detects it and pushes back. This separates objects and governs how they meet, deflecting or deforming around each other.

But when the game's timestep is too large, fast-moving objects can end up directly on top of each other — that is, with the same position coordinates — before the system has figured out that their boxes have intersected. "Then the [penalty] forces that are trying to push them away cancel out," explains Berrier. "All of a sudden, both objects are stuck there."

Other physics appeared to be missing entirely. In one in-game puzzle, the player must stack a series of crates to build an escape route. A review site called HonestGamers noted that, in these scenes, players had to be careful with how they positioned the crates, which tended "to slide off of one another as if they have no friction."

"This is a classically difficult problem," says Berrier. "When you have two rigid bodies, things can't deform. What holds them together [in the real world]? Friction. But we don't typically simulate friction because it's very [computationally] expensive."

Game developers today know how to solve this problem. "Nowadays the easiest solution is to turn [a set of objects] into a kinematic system," he explains. "If something is on top of something else, you make it a 'child' of that by joining it to the 'parent' — not rigidly, so that it is still allowed to move on its own, but that any way the 'parent' moves, the 'child' will move as well."

He says developers often use this technique with the player's character. "If they get onto a movable platform, and you want them to move as if they're in it, like an elevator, we just make that one continuous kinematic system."

All these solutions were missing from *Trespasser*, in part because they didn't exist yet, but also because the game's developers ran out of time to build them. Although these fixes "are very expensive and not fun to implement," Berrier says they're crucial for making a game's physics engine robust and its gameplay seamless.

Despite its woes, *Trespasser* will be remembered as the driver of many advances in video game design. For example, DreamWorks Interactive, which produced *Trespasser*, launched the *Medal of Honor* game franchise a year after, in 1999, building off the physics engine used in *Trespasser*. In 2004, Agent Bond returned to the game screen in *GoldenEye Rogue Agent* with a fully-fledged physics engine — this time, complete with ragdoll physics, which allowed Bond to lift "goons" with realistic motion and chuck them into other bad guys (a fan favorite).

In 1998, though, *Trespasser*'s "developers were in a new frontier with their physics engine," says Berrier. "What students learn in a classroom nowadays ... they were learning on the job, because it hadn't been done before."

Liz Boatman is a staff writer for APS News.

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view's value to the scientific enterprise — and debating its future.

APS News spoke with Rachel Burley about the changing landscape of scientific publishing and its impacts on peer review. *This interview has been edited for brevity and clarity.*

Today, scientists face a strong pressure to "publish or perish," and the amount of published research has grown enormously over the last few decades. Why? How are these changes affecting peer reviewers?

The peer review crisis is worse in some disciplines than in others, but the mushrooming of research output you described is behind it. In my mind, this started when the mega-journals arrived in the early 2000s. Those publications moved away from selectivity and novelty. They weren't necessarily asking reviewers to look for something new and different; they were saying, "If it's technically sound, we'll publish it."

I don't think that's necessarily a bad thing, but it created a new set of previously unpublished research. And because, in the open access model, every paper published is potentially revenue-generating, new publishers entered the space. So you have this combination of pressure to publish — the "publish or perish" you mentioned — and more papers being sent for review, because there are more journals with lower selectivity.

This whole ecosystem has led to bigger pressure on peer reviewers, with more manuscripts to review without more time to do it.

How are publishers trying to solve this?

Publishers initially focused their efforts on streamlining the process by finding ways to reduce the time to peer review — for example, by finding the right reviewer for the paper in the first place. And they have tried to increase efficiency through automation or by taking over parts of the peer review process that a peer reviewer can't reasonably be expected to do, like submission checks, to ensure the manuscript is in the best shape possible for the reviewer, so they're only being asked to look at the science.

Many publishers have also invested in reviewer training. In general, there isn't formal reviewer training — you might be lucky enough to find someone to mentor you through the process, but a lot of reviewers don't know what kind of feedback is required from them.

But the research volumes are such that, even combined, all these efforts don't necessarily fix the problem.

Many argue that a diverse pool of peer reviewers can improve research and reduce bias, including the bias that shapes who gets published. What are journal publishers doing to improve the diversity of that pool?

There's increasing recognition that publishers have an important role to play here. Some publishers are creating reviewer databases that capture not just the researcher's expertise and background but also demographic information to be more inclusive — and they're partnering with organizations that represent underrepresented groups.

Publishers are also experimenting with either double-anonymous peer review, which has been said to eliminate some bias, or fully open and transparent peer review, where the reviewer reports are published with the paper. The argument is that it's harder to be biased if everything's in the open record. But neither has been proven perfect. And in physics, it's particularly difficult because we have arXiv. If people really want to know who's written a paper, they can almost certainly find out.

In your mind, what are the limits of open peer review?

If you're going to be reviewing a paper for somebody well-known in your field and more senior than you, then you almost certainly don't want to critique that paper in a negative way, because that could harm your career prospects. At least, that's how some people would view it.

There's also time commitment. To have it published openly, you're going to take more time than you would on something that's confidential between you and the editor. A lot of people feel that time commitment is a big ask, so they would rather not do an open review.

Another challenge for peer review is the rise of interdisciplinary research. How can journals ensure that studies that cross traditional discipline boundaries are evaluated rigorously?

Journals can work to assemble multidisciplinary groups of reviewers. Not everybody's going to have expertise across all the disciplinary areas, but as a group, they have a better chance of covering multidisciplinary research.

And transparency might help. If you can be transparent about how interdisciplinary research is reviewed, then you can build on the credibility of the process. It might mean you provide information, as a publisher or a journal, about the expertise of the pool of reviewers you used and how you incorporated their feedback.

There's a role for journal editors, too, who can guide the peer review process to make sure they're getting the right feedback on interdisciplinary studies. And editors can help authors by providing clearer explanations of the concepts they're covering — the terminology of the fields, or information that can help reviewers understand concepts in the paper. Peer review is especially important in interdisciplinary research because the readers won't be expert in everything.

Peer review might seem especially slow in physics because of arXiv.org, where preprints are quickly uploaded. How are publishers thinking about the speed of peer review?

In physics, it's commonplace to post your original manuscript to arXiv for feedback before or during the publication and submission process.

The focus on speed of publication has caused publishers to get creative — create automations, outsource some elements of the manuscript assessment, monitor and reduce the turnaround times at each phase.

But the downside of rapid peer review and publication is that some things are published that shouldn't be, and there's a risk of increased research fraud, which can fall through the cracks.

Do you think publishing can be too fast?

There's a balance to be had between speed and rigor. How do you make publication faster, while making sure you can trust it and there has been rigor around peer review? Of course, that's the role that journals have traditionally played. You have expert teams working for trusted journal brands saying, "Here's what's worth reading and that we're validating."

Is it perfect? No, but a perfect alternative has yet to be found.

Open access publishing is growing, bolstered in part by the White House's announcement last year that federally funded research must be available to the public by the end of 2025. How are these shifts impacting peer review?

Most publishers are in the process of transitioning to open access including APS. We have open access and hybrid options in the *Physical Review* journals, and we participate in the Sponsoring Consortium for Open Access Publishing in Particle Physics.

While open access enhances accessibility, it also requires funding models. In the US, the White House and the agencies have not said they're advocating for any one business model, but it's clear that the "green route" to open access — depositing an author-accepted manuscript immediately on publication without a 12-month embargo — relies on the subscription model. As more content becomes open, that model becomes unsustainable.

It leaves academic publishers in the situation the industry is in now, where we're trying to work through what a sustainable funding model looks like to ensure that we can continue to conduct rigorous peer review in an open access world.

How is artificial intelligence shaping peer review? What are its benefits and risks?

There are beneficial uses for AI, if done carefully, like automating various aspects of the process — matching manuscripts with the right reviewers, identifying potential ethical issues, assessing the language quality and writing. All these things can be done reliably with AI now, and they can increase efficiency and take those tasks away from editors and reviewers, to allow them to focus on the science.

There's also the possibility that AI becomes so good that it actually can do peer review. Of course, nobody believes that right now, but we also didn't believe that open AI would be at the stage it is today. ChatGPT is passing college exams.

The challenge, though, is that AI algorithms can inherit biases from the data they're trained on. It could lead to even more bias, like biased reviewer recommendations. We have to ensure we're making efforts to eliminate that and reduce unintended bias.

There are also ethical considerations around privacy and data security and transparency. Authors and reviewers need to be aware of how their data is being used and who has access to it.

And there are some things AI tools are still not capable of doing — evaluation that you need human judgment for. AI algorithms can't yet determine what's novel or groundbreaking. They've been trained on existing research, and it's new discoveries we're looking for.

Taryn MacKinney is the Editor of APS News.

> "AI algorithms can't yet determine what's novel or groundbreaking [in research]. They've been trained on existing research, and it's new discoveries we're looking for." — Rachel Burley

White House Sets Research Priorities for 2025, Emphasizing "Trustworthy" AI and US Competitiveness

BY JACOB TAYLOR

Credit: Bill Chizek / Adobe

The White House released its annual R&D priorities memo on Aug. 17, intended to inform science agencies' budget requests for fiscal year 2025. The memo stresses that agencies will need to make "clear choices" in the face of new limits on federal spending.

Issued, as always, by the Office of Science and Technology Policy and the Office of Management and Budget, the memo is the first to be signed by Arati Prabhakar, who was sworn in as OSTP director and President Biden's science adviser last October.

At four pages, the memo is less than half the length of last year's, but lists new priorities, including "trustworthy" AI development, regional innovation, research security assistance, and benchmarking US competitiveness in science and technology. It also encourages agencies to experiment with "new approaches" to research funding. Largely unchanged are priorities related to strengthening the STEM workforce, promoting equity and inclusivity in STEM, addressing climate change, and bolstering national security.

Compared to last year's memo, the administration is emphasizing the need to develop "trustworthy" artificial intelligence; the memo calls AI "one of the most powerful technologies of our time." It instructs federal agencies to develop new AI tools for a suite of ambitious goals, including — among other things — to "advance solutions to the nation's challenges that other sectors will not address on their own" and "tackle large societal challenges."

The memo also calls for agencies to help design regulations to mitigate threats that AI poses to "truth, trust, and democracy."

The memo also calls on agencies to "assess and benchmark" US technological competitiveness — an instruction related to the CHIPS and Science Act, which requires OSTP to produce quadrennial reviews on the state of global competition in science and technology, potential threats to US science and technology leadership, and opportunities for international collaboration.

The memo also backs recent efforts to foster regional innovation — that is, to develop technological hubs across the US, beyond existing hubs like Silicon Valley. Congress supported such efforts through the CHIPS Act, and the Biden administration has pushed ahead with NSF and Commerce Department programs, authorized by the act, that invest in regional initiatives. However, the act's ambitious vision is unlikely to be realized under tightened budgets.

As part of its focus on regional innovation, the memo also directs agencies to emphasize "emerging research institutions and historically underserved communities." Recent agency initiatives include the Department of Energy's RENEW (Reaching a New Energy Sciences Workforce) and FAIR (Funding for Accelerated, Inclusive Research), which focus respectively on diversifying the workforce through training and building institutions' capacity for research. NSF is also ramping up efforts: Its GRANTED (Growing Research Access for Nationally Transformative Equity and Diversity) initiative, for example, aims to help institutions better support federally funded research.

The memo further directs agencies to support the academic and industrial sectors in "identifying and addressing research security challenges." While protecting research against exploitation by rival governments has been a federal priority for years, last year's memo did not explicitly address it.

Jacob Taylor is a senior editor of science policy at the American Institute of Physics.

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Climate Doomism Disregards the Science

Climate change is a highway, not a cliff, and we can still take the exit ramp.

BY MICHAEL E. MANN

Climate models are fuzzy, rather than clear crystal balls. They provide important guidance, in many respects our best guidance, drawing upon the laws of physics, chemistry, and biology to make quantitative, rigorous projections of our potential futures. That's a whole lot better than relying upon hunches, opinions, and wild speculation. The overall warming of the planet, for example, is very much in line with early climate model predictions. But when it comes to *some* key climate change impacts, such as ice sheet collapse, sea level rise, the retreat of arctic sea ice, ocean conveyor slowdown or collapse, western North American drought, and the increase in extreme weather events, the absence or poor representation of importance processes in the models leads to a systematic underestimate of the rate and magnitude of the changes.

Credit: Antonio Rodriguez / Adobe

Such nuanced views struggle to gain currency in a political economy where hot takes, hyperbole, and polarizing commentary best generate clicks, shares, and retweets. I often encounter, especially on social media, individuals who are convinced that the latest extreme weather event is confirmation that the climate crisis is far worse than we thought, and scientists and climate communicators are intentionally "hiding" the scary truth from the public. It is the sort of conspiratorial thinking that we used to find among climate change deniers, but increasingly today we see it with climate doomists. Such sentiment emerged, for example, during the mid-June 2022 heat wave, where one individual tweeted at me and my climate scientist colleague Katharine Hayhoe: "Again we see that climate science as often presented to the public is too conservative, avoids what at the time are deemed worse [sic] case scenarios. BUT these are becoming our reality TODAY."

This is not true, or at best partly true. I responded, "Actually, the warming of the planet is very much in line with early climate model predictions. Some impacts, such as ice sheet melt and sea level rise, and the slowdown of the ocean 'conveyor belt' are exceeding those predictions." Current policies alone likely keep warming below 3°C (5.4°F), nowhere near the "worst-case" scenarios. That doesn't mean that some impacts aren't unfolding earlier and more dramatically. They are. As the great Stephen Schneider counseled decades ago, it's neither "end of the world" or "good for you." The collective evidence supports *neither* fatalism *nor* complacency.

It is also important to recognize that climate change isn't a cliff that we go off at certain thresholds of planetary warming such as the oft-discussed 1.5°C (2.7°F) warming level, though it is often framed that way. Climate action isn't a binary case of "success" or "failure."

A better analogy is that it's a dangerous highway we're going down. We need to take the earliest exit ramp possible. Dangerous climate change impacts, as we have seen, are already being felt — in the form of devastating droughts, heatwaves, wildfires, floods, and superstorms. Supply chains have been disrupted through a combination of a pandemic — which is likely at least in part a result of ecological destruction — and more extreme weather, sometimes with disastrous consequences, such as shortages of baby formula. Extreme heat is leading to substantial decreases in worker productivity, costing the US economy alone nearly 100 billion dollars a year. Dangerous climate change cannot be avoided. It's already here.

So, it's a matter of how bad we're willing to let it get. Worse impacts can be avoided if we limit the warming below 1.5°C (2.7°F). But if we miss that exit off the carbon emissions highway, 2°C (3.6°F) is certainly preferable to 2.5°C (4.5°F). And if we miss that exit, 2.5°C (4.5°F) is certainly preferable to 3°C (5.4°F). Consider, for example, the matter of species extinction. The IPCC estimates as much as fourteen percent of species could be lost at 1.5°C (2.7°F) warming and eighteen percent at 2°C (3.6°F). Tragic for sure, but greater rates of extinction are expected from other unchecked human activities, including habitat destruction and human exploitation of animals.

However, the number climbs to twenty-nine percent at 3°C (5.4°F), thirty-nine percent at 4°C (7.2°F), and forty-eight percent at 5°C (9°F). Half of all species would, by any reasonable standard, constitute a sixth extinction event rivaling the great extinctions of Earth's geological past. But that is avoidable in a scenario of meaningful climate action.

Despite the breathless claims of climate-driven mass extinction that one sees all too often in today's headlines, we are not yet remotely committed to such a future. We can avoid catastrophic climate impacts *if we take meaningful actions to address the climate crisis*. Yes, that's an important "if." But the science actually tells us it's doable. One of the important developments in climate science over the past decade is the recognition that greenhouse warming depends on cumulative carbon emissions up to a given point in time. This has led to the concept of the carbon budget, which determines how much additional carbon we can afford to burn and still limit warming to below a particular level.

The conventional wisdom was once that warming would continue on for decades even if we stopped emitting carbon into the atmosphere due to the sluggishness of the oceans, which continue to warm up even after CO2 stops increasing. This is known as committed warming. But committed warming is only half of the story, an artifact of simplistic early climate modeling experiments in which CO2 levels are kept fixed after the hypothetical cessation of emissions.

> As the great Stephen Schneider counseled decades ago, it's neither "end of the world" or "good for you." The collective evidence supports neither fatalism nor complacency.

Later, more comprehensive simulations with interactive ocean carbon cycle dynamics revealed that CO2 levels actually drop after emissions cease as the oceans continue to draw carbon down from the atmosphere. That decrease in the greenhouse effect cancels out the committed warming, and the result is an essentially flat line. In other words, global temperatures stabilize quickly once net carbon emissions drop to zero.

As a consequence, we can calculate the carbon budget for a particular global temperature stabilization target. To keep surface temperatures below 1.5°C (2.7°F), for example, carbon emissions have to be brought to zero within three decades, and we have to get halfway to zero within a decade. There are some confounding factors. For example, when coal burning ends, there is a drop in cooling sulfate aerosol pollution, which leads to warming. But that warming is largely offset by a decrease in other warming factors, including greenhouse gases like methane and black carbon from fossil fuel burning. These additional factors all nearly cancel as well.

There are scenarios where global temperatures exceed a given target such as 1.5°C (2.7°F), rise as high as 2°C (3.6°F) or so by mid-century, and then come back down and stabilizes below 1.5°C (2.7°F). This is called overshoot, and a shorter-duration, small overshoot is favorable, from a climate-impact standpoint, to a longer-duration, large overshoot. Once again, there are no absolutes. The less, and shorter duration, the warming, the better. But the most comprehensive and authoritative assessment of risk across all sectors — health, food, water, conflict, poverty, and the natural ecosystem — by the IPCC in 2018 basically concluded that we don't want to warm the planet beyond 1.5°C (2.7°F), and we *really* don't want to warm it beyond 2°C (3.6°F). And if we do happen to overshoot those targets, we want to keep the duration of overshoot to a minimum.

Where do we stand in this effort? Scientists have evaluated the upwardly revised commitments made at the United Nations Climate Change Conference (COP26) in Glasgow in late 2021 and have determined that they would likely keep warming below 2°C (3.6°F). That's substantial progress compared with the roughly 4°C (7.2°F) warming that we were headed toward prior to the 2015 Paris summit. But it's still a lot riskier than limiting warming to 1.5°C (2.7°F). Moreover, it's one thing to make commitments, and something else entirely to keep them. As my colleague Susan Joy Hassol and I explained in a *Los Angeles Times* op-ed published at the completion of COP26, the goal of limiting warming to 1.5°C (2.7°F) is still alive but "*only if the hard work begins now*" (emphasis added).

Among other things, a pathway to 1.5°C (2.7°F) requires there be no new fossil fuel infrastructure at a time when pipelines continue to be built. A handful of fossil fuel companies — including ExxonMobil and Gazprom (Russian state fossil fuel company) — are planning for new projects that will produce about 200 billion barrels of oil and gas. That's the equivalent of a decade of emissions from China, the world's largest producer of carbon pollution (the United States, meanwhile, is the world's greatest cumulative producer of carbon pollution).

Holding policymakers, opinion leaders, and corporations accountable is essential. For while citizens themselves now overwhelmingly support concerted climate action, they can't effect the needed changes themselves. We, as individuals, can of course make climate-friendly choices as consumers. But we cannot impose subsidies for the renewable energy industry or remove them for the fossil fuel industry, price carbon, or block major fossil fuel infrastructure projects. It is only our elected policymakers who are in a position to do that.

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This article is an excerpt from Our Fragile Moment: How Lessons from Earth's Past Can Help Us Survive the Climate Crisis, *by Michael E. Mann.*