

Mingling art and science opens minds

Collaborations enrich science communication, visualization, and inspiration.

After viewing *Little Shop of Horrors*, Andrew Pelling and his research group wondered if they could create a plant with muscles. They were inspired by Audrey II, the monster plant that eats people in the 1986 film. They tried and failed to grow muscle tissue on a leaf, but the attempt sparked a research direction that has blossomed in Pelling's group over the past decade: plant- and polymer-based scaffolding for growing mammalian tissue. Recently, he says, they have shown that an asparagus-derived scaffold can guide the growth of neurons for use in treating spinal cord injuries. They have also been studying a new polymer scaffold developed by a textile artist in the lab.

From the start, Pelling's research group in the physics department at the University of Ottawa has included a mix of scientists and artists—sculptors, painters, digital media artists, and others; at present 3 of the roughly 15 members are artists. “Every artist I’ve known is busy questioning and investigating the world, just like scientists,” Pelling says. He aims to generate questions that haven’t been asked before. “For me, the best way to do that is by having diverse people around, sharing lunch, shooting the breeze.” The interactions, he says, have led to both museum pieces and scientific advances.

Science and art often are compartmentalized—as is also the case for subdisciplines within science. But it hasn’t always been like that—consider, for example, Leonardo da Vinci, who studied friction and other topics, or his 15th-century contemporary Piero della Francesca, a painter and author of mathematical treatises. Today, connections range from science-inspired art, to art as a vehicle to explain or illustrate science, to science explored by artists, to—perhaps most rare—collaborations that advance scientific understanding.

Indirect inspiration

Ágnes Mócsy is a professor of physics and astronomy at the Pratt Institute, a school in Brooklyn, New York, that emphasizes art, design, and architecture.



IN HIS PAINTINGS, structural biologist David Goodsell incorporates known information and best guesses to portray detailed views of molecular structures. This watercolor is titled *SARS-CoV-2 Fusion*, 2020. (Illustration by David S. Goodsell, RCSB Protein Data Bank; doi: 10.2210/rcsb_pdb/goodsell-gallery-026.)

For her, Joseph Stella's paintings of the Brooklyn Bridge invite a discussion about the Doppler effect. Jackson Pollock's paintings suggest momentum and energy and fluid dynamics. Sculptures can be used to talk about mass and space, and from there general relativity. And comparing artworks from Eastern and Western cultures elucidates different senses of space and time. “When you are in front of a

painting or a sculpture, there are no right or wrong answers, so people can feel more comfortable opening up,” says Mócsy, who previously worked in heavy-ion theory at Brookhaven National Laboratory and now focuses on physics education with an emphasis on the intersection of physics and the arts. Physics often alienates people, she continues. “I am interested in enriching the narrative

we tell about physics. Art, science, and social justice are interlinked in my work.”

Like Mócsy, Kathryn Schaffer left a research-intensive career to teach physics to artists. (She describes her exit from a toxic physics culture and more about her life and career in an interview at <https://physicstoday.org/schaffer>.) Since 2009, she has overseen the science program at the School of the Art Institute of Chicago. She started a scientist-in-residence program there and frequently invites scientists to give lectures. Whereas science does not rely on art, she says, science is “integral in the art world”—from tools and techniques to the themes that artists address. Still, artist–scientist collaborations are valuable for scientists in ways that are hard to measure, she says. For example, creative cross-disciplinary collaborations can “refocus attention on who we are as curious, caring, and unique humans engaged in the practice of science.”

In 2003, as a director of a new center in Oslo, Norway, on the physics of geological processes, Bjørn Jamtveit brought in painters, photographers, and other

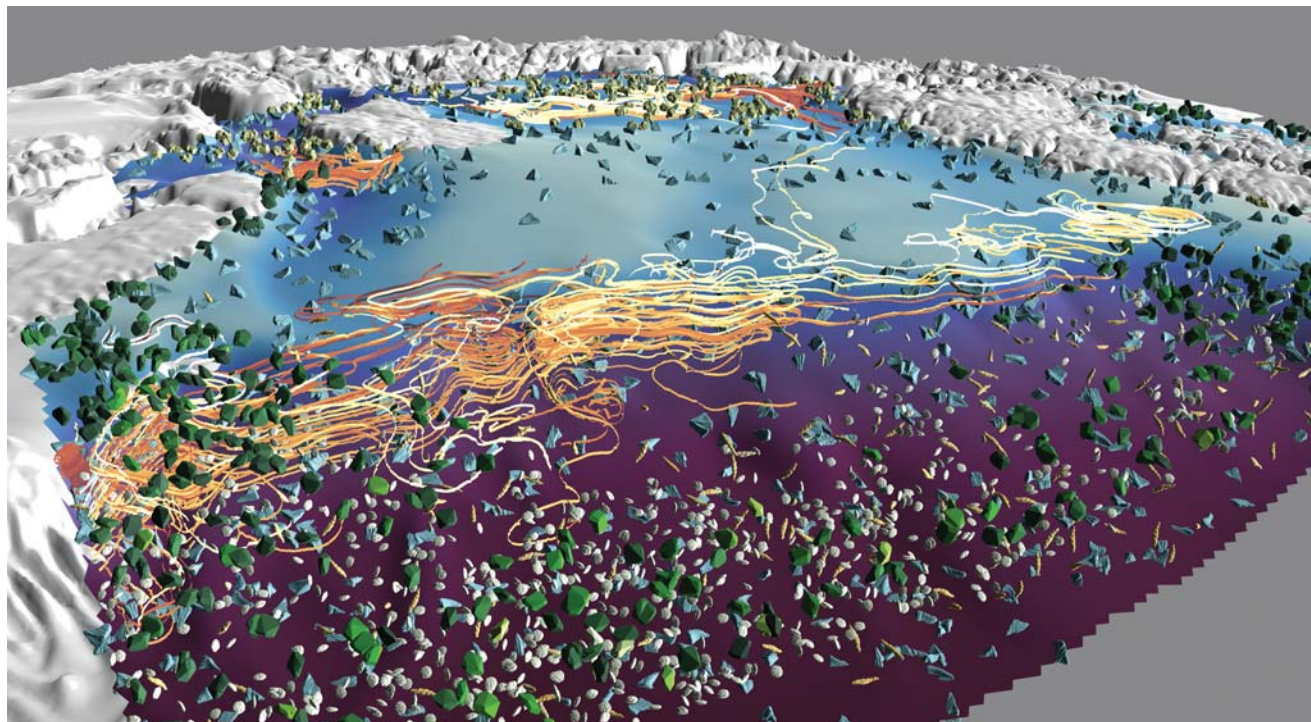
artists to collaborate with the center’s scientists. A composer worked with a scientist who was studying stress in rock deformations to create works using geological sounds; one was a walk-in installation that surrounds visitors with the sounds of cracking rocks. (Examples of sound from art–science collaborations can be found at the online version of this story.) Scientists are supposed to be objective, but often they see what they are looking for or what they recognize as familiar, says Jamtveit, who originally pursued the collaborations to increase the chances of future funding by excelling in outreach. “I’ve become a better observer because of my interactions with artists,” he says.

Early on in their long collaboration, recalls Harvard University’s George Whitesides, photographer Felice Frankel told him that his picture of water spreading on a surface was “boring” and that she could do better. That challenge and her aesthetic interests led to insights into how fluids behave at small scales, says Whitesides. “Nothing captures attention like a good photograph. If you see an ar-

resting photograph, you ask, Why is that happening? That is an asset to science.”

For her part, Frankel says scientists often crowd figures with captions, scale bars, and more. “Compositionally, you don’t know where to look.” She asks scientists what they want viewers to see first. “I use design principles for the purpose of communicating science, not to create art,” she says. “When people understand what they see, they become more engaged.”

As scientists are increasingly pressed to justify their use of taxpayer money, outreach has expanded. It includes illustrations in journals, grant proposals, and activities with the public. Geraldine Cox is an artist—with an undergraduate degree in physics—who is embedded in the physics department at Imperial College London. (Cox’s paintings appear on the cover and inside the March 2021 issue of *PHYSICS TODAY*.) She creates workshops for children, the public, and physicists. They explore the Sun, atomic spectra, and other phenomena using painting, light, and poetry. For example, in an activity based on sculptor Alexander Calder’s



SIMULATING OCEAN CIRCULATION gives clues about climate change. This view toward the South Pole is a snapshot of the Antarctic ice sheet. The yellow and orange squiggles are currents, and light blue to purple represents increasing water depth, with the transition to purple indicating the continental slope. The tracers indicate parameters such as salinity and ice shelf water. The US Department of Energy’s Energy Exascale Earth System Model incorporates hundreds of variables and has a resolution of 10 km. (Courtesy of the Sculpting Vis Collaborative, Daniel Keefe, and Francesca Samsel, funded by NSF #IIS 1704604 and 1704904.)

work, she had atomic physicists make mobiles out of items they found in their lab. “People made things about atoms and light, life and research, or set themselves practical goals like building a mobile upside down,” Cox says. “It was an afternoon of playfulness and openness.”

Denmark has a long tradition of public science outreach, says University of Aarhus quantum theorist Klaus Mølmer, and it’s “exploded” since 2005, the World Year of Physics. (See the letter “Lessons learned from the World Year of Physics,” by Laurence Lavelle, *PHYSICS TODAY*, December 2005, page 15.) When artists and scientists get to know each other, Mølmer notes, “you get collaborations.”

Mølmer has teamed up with artists, including composer Kim Helweg. “We discuss quantum mechanics in detail, he asks me questions, and then he goes and does whatever he wants,” says Mølmer. “The inspiration is indirect in both directions.” The questions that artists ask him are “an eye-opener,” he adds. “I don’t think there is a big difference in the source of inspiration for physics and art.”

Another quantum physicist-composer collaboration is that of Maciej Lewenstein and Reiko Yamada at the Institute of Photonic Sciences in Barcelona, Spain. Experimental musicians overlap in their aims with scientists, says composer Yamada. “We push boundaries, make discoveries, and experiment in new

areas.” In one project, she incorporates into musical timbres random nudges generated by quantum processes. “We compare the sounds with classical randomness. Is it different? Is it recognizable?” says Yamada. Early data suggest that timbres are distinguishable. “If people can hear the difference, it would lead to questions about cognition,” says Lewenstein. “The quantum world is not intuitive, so it creates public interest and excitement,” he adds.

Tools for science

Art plays two major roles in science, says David Goodsell, a structural biologist at the Scripps Research Institute in La Jolla, California. Visualization tools help scientists see their science, he says, and art is used to communicate science. “I’ve been working on a third aspect,” he says. “I use art to generate scientific hypotheses. My art is focused on being a tool for science.”

Goodsell has painted the coronavirus life cycle, the influenza vaccine, lipid droplets, and other subjects. He integrates current knowledge with informed guesses and aims to stretch scientists’ intuition and understanding. The paintings involve many approximations and decisions. The SARS-CoV-2 spike protein, for example, undergoes complex conformational changes as it directs the fusion of the virus with a cell (see the figure on page 24). “Structural snapshots are avail-

able for the beginning and final states, but I use artistic license to speculate about intermediate states,” he says. “I have to pick among hypotheses. I do these pictures in collaboration with specialists. It’s often difficult to get them to pin down and commit without qualifiers.” Yet the paintings lend freedom to the scientists because they are “artistic renditions,” he says.

Francesca Samsel uses her skills and sensibility as an artist to help scientists extract more information from vast data sets. She has worked closely with several scientists from Los Alamos National Laboratory for nearly a decade on such topics as climate modeling, ocean biogeochemistry, and the waves created by asteroid impacts. A current project with ocean modeler Mark Petersen and others involves Antarctic ice melt and ocean circulation (see the image on page 25).

“In the arts we are trained to use visual elements—lines, shapes, color—to create relationships between variables, organize content, and direct attention,” says Samsel. That can be done with color, she adds, “but you have to know how to use it.” Traditional rainbow-colored maps can lead to visual artifacts, she notes. What’s more, in such maps, fully saturated colors are adjacent, which causes visual vibration that tires viewers’ eyes.

The key to artist-scientist collaborations is leaving assumptions at the door, says Samsel. “Scientists have to leave

Facing page (clockwise from top left):

CURVED THREE-DIMENSIONAL LATTICES are depicted here by artist Tony Robbin, who works closely with mathematicians. The braided lattices are color coded and identified by different polyhedra. In higher dimensions, the lattices flow over and under each other, he explains, but in projection they appear to intersect. The painting, *2006-6*, is acrylic on canvas, 56 × 70 inches, from the collection of the artist. (Courtesy of Tony Robbin.)

CHIXEL ARRAY is a light sculpture made of stuff bought from a dollar store and scavenged from the garbage. It started with the idea of lighting toy chickens with pixels, and involved designing a circuit and coding. “It’s goofy and esoteric,” says University of Ottawa biophysicist creator Andrew Pelling. But, he says, “it symbolizes how my lab works. Beneath it all, a scientific team is being cultivated to take on any project—a team that is comfortable with troubleshooting, iteration, and pivoting as a project proceeds.” (Courtesy of Andrew Pelling.)

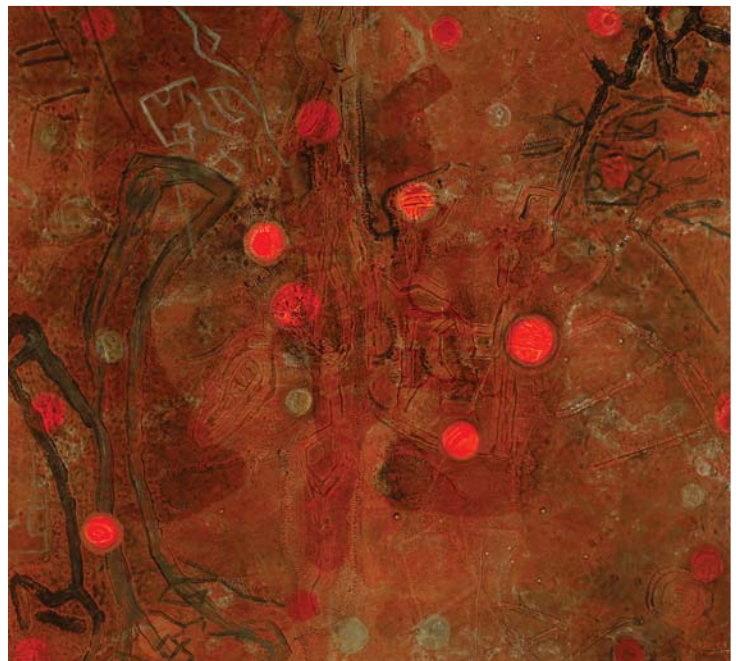
ENTANGLED WEBS in this image are woven by different species of spiders. It is from *Arachnophilia*, an interdisciplinary research project started by Berlin-based artist Tomás Saraceno that probes spider web architecture, vibrational signaling, and more.

Saraceno developed a scanner to digitalize spider webs and has recorded the sounds of vibrating web threads. (Image from Photography by Andrea Rossetti, ©2013.)

GEOPRINT is a series by artist Ellen Karin Mæhlum. She joined scientists from the University of Oslo’s center on the physics of geological processes on an Arctic expedition in Svalbard to explore the relationship between rock and life forms in a Mars-like environment. Based on forms and patterns on different scales, the images, including *P0911* shown here and *V7010* on the cover, were formed in layers using printing plates, drypoint, and stencils. (Courtesy of Ellen Karin Mæhlum, www.ellenkarin.no.)

ACOUSTICALLY LEVITATED water droplets resonate, vaporize, and reassemble as they spin nearly devoid of shear. Creators Evelina Domnitch and Dmitry Gelfand describe *Force Field* (2016) as tapping into the three-dimensionality of sound, the elusive physicality of water, and the rotational dynamics of celestial and subatomic bodies. (Courtesy of Evelina Domnitch and Dmitry Gelfand.)

COFFEE BUBBLES move and burst. The photo was taken through a microscope that was fitted with a smartphone adapter. (Courtesy of Felice Frankel.)



aside the idea that I may be flaky. And I have to work to understand the science and the scientists and their needs.” The process is iterative, she adds. “It’s thematically rich and symbiotic.” Petersen notes that “Francesca is deeply embedded—she is part of the team.”

To depict simulations of the waters under the Antarctic ice shelves, Samsel introduced tracers based on hand-sculpted forms. Textured, shaped, and shadowed, different tracers allow the viewer to distinguish between multiple variables—temperature, salinity, currents, water depth, and more. Such an image can be digested more easily than when the variables are represented by colored spheres. In virtual reality, the scientists can swim up close or zoom out to study the data from a range of perspectives. “The goal is complexity without cacophony—a calm, clear environment of visual clues,” says Samsel.

Different questions

Evelina Domnitch and Dmitry Gelfand are an artist couple based in the Netherlands who create performances and installations that are deeply rooted in science. “We are interested in art that prods uncharted perceptual physical and philosophical domains,” says Gelfand. When they began working together more than two decades ago, he says, “we opted to work with gases, fluids, and wave phenomena. This was an unorthodox constraint in the arts. It was inspired by quantum theory.”

The duo’s explorations include sonoluminescence, acoustic levitation, black



JESSICA SMOLINSKI

SUZANNE BROWN (right) discusses her painting *dis,oRdered* with Stephanie Wiles, director of the Yale University Art Gallery. The self-portrait explores entropy, heat transfer, and time, and makes an analogy with everyday feelings of disarray and stress. Brown painted it in 2019 during an undergraduate course, *Physics Meets the Arts*, taught by Ágnes Mócsy, who was a visiting professor in the Yale physics department from the Pratt Institute.

holes, and ion traps. Domnitch and Gelfand learn the relevant science. “One of our reasons for confronting these exotic physical phenomena is to come to terms with the nature of reality,” says Domnitch.

In their piece *Camera Lucida*, the artists

transmit sound waves into a 60-liter glass sphere containing gas-infused water to induce sonoluminescence. “High-frequency sounds form microbubbles. When they collapse, they reach temperatures as high as in the Sun and emit faint flashes,” says Domnitch. Kyuichi

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Yasui, a theorist at Japan's National Institute of Advanced Industrial Science and Technology in Nagoya, says that it was interesting to watch the bubbles and sonoluminescence in the work "because the container was much larger than in laboratories." Although there was not a direct connection to his research, he adds, "when I see art, my stress in research disappears, and my passion from the art is useful for my research."

Another artist whose work is steeped in science is Berlin-based Tomás Saraceno of Argentina. "We need to reinvent our modes of collaboration and to work across disciplines," he says, because of the scale of problems humanity is facing: global warming, mass extinctions, human suffering. Saraceno's projects include digitizing and reconstructing spider webs and recording the vibrations spiders make in their webs. "Now I think of the web as a musical instrument," he says. "A spider senses or locates prey by tuning its web; energy propagates through the web's threads." The three-dimensional reconstructed spider webs have been compared with cosmic webs, he notes. "You can scale up and think about the visual effects and the harmonics and musical scales."

Andrea Polli's installation *Particle Falls* is similarly science based. The University of New Mexico professor and environmental artist displayed particulate-matter concentrations on streets in Philadelphia and other cities. The data, updated every 15 seconds and projected onto a building, visualize unseen pollution.

Art can help science by opening doors to what needs to be understood, says Tommaso Calarco, director of the Institute of Quantum Control in Jülich, Germany. Artists ask different questions, inspiring new ways of thinking. And artists present ideas in ways that are "beautiful, appealing, exciting, and emotional." Domnitch and Gelfand, says Calarco, make science experiments "beautiful to behold and thought provoking. They create a sense of wonder, and that can inspire scientists to approach their research differently."

Calarco says interactions with art and artists "form a strong anchor and inspiration in shaping the direction" of his work in quantum thermodynamics. "If we forget that science is beautiful," he says, "we will have the innovation of tomorrow, but not of the day after tomorrow."

row. It's wise to pursue the useless side of knowledge."

Art and science both value economy and intensity, says Roald Hoffmann, a chemistry Nobel laureate at Cornell University. "This is obvious in poetry, and in a different way, equations or explanations communicate best when they are concise." But a difference, he says, is emotion. "Artists, poets, musicians, dancers, are good at communicating with emotions. But science by and large rules out

emotions." And that, he says, "is absolutely wrong." He notes that scientific lectures tend to be much more interesting than papers, "and it's because they [lecturers] are weaving together a story with emotional descriptors along the way." Communicating emotion is something science can learn from the arts. "I am interested in building an intellectual community. We need bridges between humanities and science."

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