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In late February Mahesh Bandi was in Trieste to give lectures at the Abdus Salam International Centre for Theoretical Physics. Northern Italy was becoming a hot spot for COVID-19, and travel to other parts of Europe was restricted; instead of continuing to Paris as he had planned, Bandi returned to his job at the Okinawa Institute of Science and Technology. Before leaving Italy, he gave away the face masks he had brought from Japan, figuring he could get more back home. He was wrong.

Since returning to Japan, Bandi has set aside his usual research—on granular materials, statistical physics of sustainable energy, the stiffness of the human foot, and more—and instead has focused on creating reusable face masks and other personal protective equipment to help medical workers stay safe from infection. He is also assisting an international agency in real-time analysis and modeling of the pandemic's spread dynamics. "It's the first time in my life that I feel all my learning is really helping people," he says.

Scientists around the world have turned their attention to COVID-19. Among the projects physicists are working on are apps for proximity tracing, mobile care deployment, and supply-chain simplification; ventilators from easily sourced parts; numerical simulations of ways to reopen civic life and reboot the economy; and molecular simulations to search for therapeutics and vaccines.

Besides creativity and handiness with electronics and computers, physicists have expertise in managing big data and large teams. And approximating is part of every physicist's training, notes John Langford, a researcher at Microsoft who helped design protocols for contact-tracing apps. "We are in a situation where the fatality rate is unclear, where many things are unclear. If you are comfortable dealing with approximate information, you can start to act now."

THE MONITOR ON THIS PRESSURIZED HELMET consists of a sensor (orange box) hooked to the expiratory hose that feeds data about the pressure inside the helmet and air flowing out to an interface box fitted with a customized Raspberry Pi computer. From those data, the pressure exerted by the lungs, the volume of air per breath, and breaths per minute can be determined. The monitor was built by Princeton University scientists in consultation with medical workers to treat COVID-19 patients.

Says Gordon Watts, a particle physicist at the University of Washington, "Everyone is eager to contribute, but we physicists have almost zero training in epidemiology, medical devices, or anything like that. It's important to engage without injecting noise."

Researchers' efforts to help combat COVID-19 have sprung up largely spontaneously. At the same time, physicists have created networks to facilitate interdisciplinary collaborations, spread successful ideas, reduce duplication, and maximize impact. "Right away, it was clear the problem will be with us for a while, it will take time to develop a vaccine, and there is a real risk of a second wave," says Princeton University particle physicist Peter Elmer, who works on the CMS experiment at CERN. "Universities and national labs have international capabilities. If we cannot respond and do

MAXIMILIEN BRICE/CERN

A FACE SHIELD PRODUCTION CENTER AT CERN gets a visit from director general Fabiola Gianotti (left). Francisco Perez Gomez (center) was one of the technicians who initiated CERN's manufacturing of face shields. His brother, Juan Carlos Perez (right), an engineer in the lab's magnet group, started a second production line at a different site. Each line made around 500 face shields a day.

something useful in this environment, who can?"

In March, Elmer and a handful of like-minded colleagues started Science Responds, an informal network to help nonmedical researchers contribute to combating the global pandemic and its fallout. CERN, meanwhile, set up a task force to coordinate ideas and support efforts related to COVID-19. "The task force is acting as a matchmaker so that ideas can be pursued immediately," says task force chair Beniamino Di Girolamo.

From visors to ventilators

Technicians at CERN churned out 15 000 face shields by hand over seven weeks. Most were distributed regionally to health workers, police officers, customs agents, and others who have significant exposure to the public. "That has been the most successful initiative in terms of immediate impact," Di Girolamo says. Lab technicians also produced 10 metric tons of hand sanitizer from a recipe provided by the World Health Organization and used 3D printing to make washable face masks. Commercial manufacturers are putting CERN's mask design into mass production, he says.

Additionally, demand for CERN's emergency vehicles soared. Typically they get called perhaps 10 times a year to take patients to the hospital for incidents unrelated to the lab. For a brief period this spring, during the peak of the COVID-19 outbreak in Geneva, they were used for the local community about 20 times per week.

CERN has also dedicated a large portion of its computational and data resources to pandemic-related projects. For example, the distributed project Folding@home, which simulates protein dynamics to help develop therapeutics, runs on computers at CERN and other labs. And scientists from the UK's Diamond Light Source and elsewhere store data from COVID-19 studies at CERN. (For more about COVID-19 work at major facilities, see PHYSICS TODAY, May 2020, page 22; for a story about physicists modeling the pandemic's epidemiology, see June 2020, page 25.)

CERN scientists designed a ventilator optimized for use in poor countries. It aims to be cheap and easy to manufacture, run on batteries, function at a wide range of temperatures, and directly connect to mobile pressure tanks, since it may be needed in areas that lack medical gas outlets. CERN's is one of many ventilator projects around the world. "They differ in details," says Di Girolamo, "and there is enough need for all of them."

Physicists are also behind the Mechanical Ventilator Milano, which is based on a simple design that uses only a few parts to enable rapid, inexpensive production. Features include push-button measurements of alveolar pressure and the ability to boost oxygenation immediately following intubation. It was developed with the help of anesthesiologists "working in the COVID-19 wards in Italy and abroad," says project spokesperson Cristiano Galbiati, who splits his time between Princeton and Italy's Gran Sasso Science Institute.

While in Milan in March, Galbiati heard through friends about the paucity of ventilators. He thought, "We scientists have the know-how to work with gases and should be able to find a way to put oxygen in the lungs of patients." Hundreds of his colleagues from the DarkSide dark-matter experiment joined the effort. "The project never stopped," says Galbiati. "It was going on in nine different time zones." On 1 May, barely six weeks after its conception, the ventilator received emergency use authorization from the US Food and Drug Administration.

Some other Princeton scientists asked clinicians at the University of Pennsylvania hospital how they could help fight COVID-19. A group that grew to more than 20 then took on the task of creating an inexpensive monitoring and alarm system for a noninvasive ventilator. The ventilator, which consists of a helmet that delivers pressurized air, reduces the amount of time patients need to be intubated on an invasive ventilator. For some patients, the helmet ventilator eliminates the need for intubation entirely. "It's basically a bag over the head," says team coordinator and Princeton physicist Andrew Leifer, "so if something happens, patients can asphyxiate."

Commercial monitoring solutions exist, says Leifer, "but the supply chain is crushed. A critical aspect of our design is that it's super robust to the medical supply chain." Within three weeks of getting started on 1 April, and working largely in their homes, the team members had built a prototype monitor. In six weeks they had produced 40 units. In May the design was tested on human volunteers, and the team is applying for emergency use authorization so it can be deployed in hospitals. The project has also piqued the scientists' interest about lung function. Says Elmer, "We could use the monitors to get data sets to see how patients' lungs evolve, to get a full picture of lungs in COVID-19 patients."

MAHESH BANDI/OKINAWA INSITUTE OF SCIENCE AND TECHNOLOGY

THIS COTTON CANDY MACHINE (diameter 70 cm) was retooled to make a high-quality filter material for face masks. The technique could enable inexpensive, local fabrication, especially in less developed regions of the world.

"Some good in this mess"

Savannah Thais, a postdoc at Princeton, uses the Science Responds network to enlist physicists and data scientists as contributors to projects related to COVID-19. So far, the network has a core of about 20 scientists and more than 200 participants total. "There is tons going on," she says. "It can be hard to parse. We want to be a central information hub and provide opportunities for conversation." An emerging goal, she adds, is to use the experience from particle physics to help other researchers with remote interactions.

When Washington University in St Louis biochemist Greg Bowman of

Folding@home reached out to Science Responds for advice on running a large distributed project, Rice University's Christopher Tunnell was happy to help. "Working in teams of hundreds, even thousands, has become second nature for us, but a lot goes into making it work well," he says, alluding to his research in computational astroparticle physics. Bowman's question "was not a physics question, it was an organizational question," Tunnell says. He shared a document that outlines how XENON, the dark-matter experiment he works on, handles organizational issues, publications, partnerships, and so on.

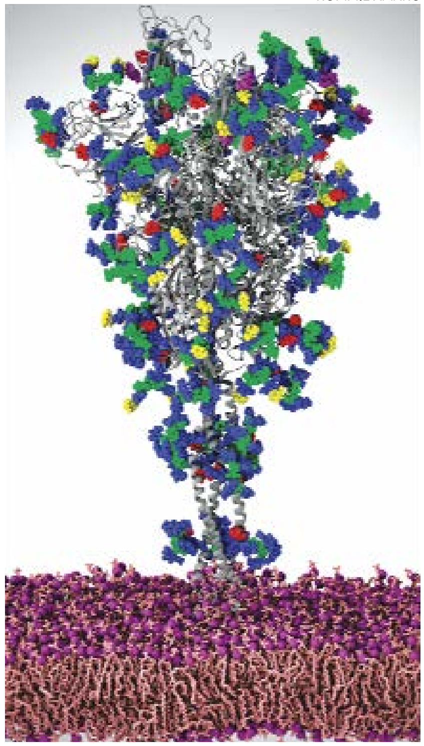
When Tunnell discovered that the pandemic was interfering with students getting summer internships this year, he hired eight of them. "These are top computer science and engineering students, and they would usually go to prestigious tech companies," he says. Some of the international students would have had to leave the country. The hires are small scale, he says, "but at least it's some good in this mess." (See also the story "Pandemic creates hurdles for academic job seekers," Physics Today online, 23 April 2020.)

Thais, for her part, is applying machine learning and other techniques to address socioeconomic impacts of COVID-19. On 17 May she and a team she assembled largely through pandemic-related hackathons launched a dashboard to track economic distress, health impacts, and other factors in vulnerable populations. It aims to inform policymakers, nonprofit organizations, and health care providers. (One of Tunnell's computer science interns is collaborating with Thais on that project.)

The novel coronavirus was an easy pivot for Rommie Amaro, a biophysicist at the University of California (UC), San Diego, who uses computational and theoretical methods to understand and design proteins and molecular machines. The virus "is one of the most complicated structures we have come across," she says. She and her colleagues are simulating the spike glycoprotein, which protrudes from the virus's surface.

Computational methods are essential because the protein is hard to crystallize. "We will get the complete structure, which you cannot get experimentally," she says. "Sugars act like a shield over the surface, and we are looking for chinks in that armor." The work, she says, could contribute to drug and vaccine design. COVID-19 will ultimately be stopped by a vaccine, says Amaro's UC Berkeley colleague Teresa Head-Gordon, a codirector of the Molecular Sciences Software Institute. For now, she says, "we are building capability to be ready for the inevitable next time a new virus is introduced and to more rapidly explore a greater range of therapeutics."

ROMMIE AMARO



A SNAPSHOT FROM A SIMULATION OF THE SPIKE PROTEIN on the surface of the novel coronavirus. Rommie Amaro of the University of California, San Diego, and colleagues are using simulations to look for vulnerable points in the protein.

At the University of Newcastle in Australia, Paul Dastoor, a physicist who heads the Centre for Organic Electronics, is exploiting his work on horse fertility to develop a rapid fluorescence test based on the viral load in saliva. Scientists at the center also jumped into action to make face shields from a flexible plastic substrate they had used for solar panels. "We thought of the idea on a Friday," he says. "On Monday people came into the lab at 6:00am, and two hours later the first prototypes appeared." After getting feedback from hospital workers, the lab built a machine that can make up to a thousand shields per day.

Bandi of the Okinawa Institute of

Science and Technology and Manu Prakash of Stanford University independently dreamt up the idea of using cotton candy machines to make face masks. Polystyrene or polypropylene, the same materials used for N95 masks, is fed into the machine, melts, and flies out through holes. It solidifies into an unwoven fabric that can form the basis for a high-quality mask. Both researchers have other COVID-related projects, such as washable masks, full-face coverings made from off-the-shelf snorkel masks for health workers, and more. They both aim to create protective gear that can be manufactured cheaply in developing countries. “In places where there is no supply chain, it changes the dynamics of what can be made locally,” says Prakash.

Trace, test, treat

Some scientists are working on contact-tracing apps to help identify and notify people who may have become infected from being near someone who tests positive for COVID-19. The new apps tend to be variations on the same theme: If two smartphones that come within Bluetooth range remain in proximity long enough—say, 20 minutes—they retain a record of that contact for a limited time, perhaps one month, in the form of an anonymized code. If someone subsequently tests positive for COVID-19 and voluntarily uploads that information, the contact codes retained on their device are used to inform others who had phones in proximity.

Many of the apps under development use Bluetooth only. University of Toronto computational chemist Alán Aspuru-Guzik is working on an app that also uses GPS. The advantage, he says, is that it helps identify infection hot spots. He adds that proximity-tracking apps should be used together with traditional manual contact tracing. The manual intervention is key for areas that don’t have good coverage, and for people who don’t opt in to contact tracing by app or don’t have smartphones.

For app designers, challenges include making sure that proximity with a barrier in between—say for people in adjacent offices—does not generate a contact record, certifying that a reported positive is valid, and attracting sufficient participation for the proximity tracing to be useful. Perhaps most challenging of all, however, is protecting privacy and assuring users that the information will be used only for the stated public health purpose.

One approach to gaining the public’s trust is to place the data in nongovernment hands. “People may trust CERN more than their own governments,” says CERN computer scientist Mario Lassnig. He and colleagues are considering a proximity tracer just for the world’s high-energy-physics labs. For now, CERN is using a system that was repurposed from its original function of keeping track of radioactive equipment. The development of apps is longer term, Lassnig says, “so we have them in place in a second or third wave of the pandemic, and we are not sitting ducks like we are now.”

Microsoft’s Langford notes that testing, tracing, and isolation are all needed to suppress the disease. “You can trade off,” he says, “but it’s not fun. You have to isolate more people if you minimize testing.”

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