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A student at the University of Warsaw assembles 3D-printed protective masks.

OPEN SCIENCE TAKES ON COVID-19

Data sharing and hobbyists are being harnessed to combat the pandemic. **By Mark Zastrow**

When reports emerged in late 2019 of an outbreak of a new coronavirus centred in Wuhan, China, researchers at the virological-analysis website Nextstrain were ready. The open-source project tracks the spread of viruses through genetic variations in the sequences that scientists find. After five years of development and operation, Nextstrain had team members on three continents who could continuously refresh the analysis, 24 hours a day.

What they didn't know was whether researchers would share their data. "You just never know what level of detail is going to be allowed to come out," says Emma Hodcroft, a Nextstrain developer and molecular epidemiologist at the University of Basel in Switzerland.

But since 11 January, when a team led by Zhang Yong-Zhen at the Shanghai Public Health Clinical Center, China, shared the first genome sequence of the SARS-CoV-2 virus, the volume of data has skyrocketed. By the end of March, Nextstrain was receiving anywhere from 50 to 200 sequences a day from laboratories around the world, and was running its analysis of virus evolution every few hours. "The volume that we're getting right now, this is totally unprecedented," says Hodcroft.

Nextstrain is just one example of how an open ethos has driven the scientific response to the COVID-19 pandemic. Academics, online data repositories and home hobbyists with 3D printers are adopting new practices of rapid data sharing and collaboration that are appropriate to the urgency of the crisis. Many hope it will change the way science is done even after the pandemic subsides.

Do it yourself

Perhaps nowhere is that open ethos clearer than in the way do-it-yourself (DIY) and 'maker' communities have stepped up. As soon as it became clear that health systems around the world were at risk of running out of crucial equipment to treat people with COVID-19 and protect medical workers, DIY-ers set about trying to close the gap.

Facebook groups such as Open Source COVID19 Medical Supplies, which has more than 70,000 members, have become dispatch centres, through which hospital workers seek volunteers to print or make supplies, and volunteers trade tips on what materials to use and where to source them, and on sterilization procedures.

The coronavirus crisis plays to 3D printing's strong points – rapid prototyping and the ability to produce parts on demand anywhere in the world. Prusa Research, a manufacturer of 3D printers in Prague, has designed a frame for a face shield that is meant to be worn outside a mask or respirator to protect against infectious droplets. The company says it has the capacity to produce 800 shields per day, and tens of thousands of the devices are already protecting health-care workers in the Czech Republic. But because the company made its designs open-source, they are also being made around the world in maker spaces and homes.

Formlabs, a 3D-printer manufacturer based in Somerville, Massachusetts, leads another project that has reached production: printing nasal swabs for COVID-19 test kits. Unlike common cotton swabs, nasal swabs must have a rod that is long and flexible enough to reach deep into the nose, to the upper throat. The swabs were designed by doctors at the University of South Florida in Tampa and the Northwell Health hospital system in New York, using printers purchased from the company to produce test versions. "They are prototyping it themselves, which is crazy and really awesome," says Formlabs's chief product officer, Dávid Lakatos. And whereas conventional swabs feature a bushy tip coating of

nylon flock, the doctors devised a tip with an intricately textured pattern that is 3D-printed.

But unlike face shields, these parts are beyond the capabilities of most printers used by hobbyists. "If someone tried to print the swabs on a hobbyist printer, they can really do harm" in a clinical setting, says Lakatos.

Under US regulations, commercial manufacturing of nasal swabs must take place in a facility that has been registered with the US Food and Drug Administration (FDA). Formlabs has its own registered lab in Millbury, Ohio, with 250 printers (each costing about US$3,500) that can print 100,000 swabs a day.

The right tool

Other 3D-printed and DIY projects seek to provide everything from protective face masks for medical workers to door handles that can be opened using an elbow — helping healthcare staff to avoid contaminating their hands — and ventilators for people who are critically ill. Among the furthest along in development are the OpenLung ventilator — a collaboration between groups based in Toronto, Canada, and Dublin — and the MIT Emergency Ventilator developed at the Massachusetts Institute of Technology in Cambridge. But manufacturing of such devices is still subject to regulatory approval. The MIT team told *Nature* that "approval would be sought by a manufacturer that ultimately adapts and makes a device inspired by the open-source reference material". On 17 April, the first such device, called Spiro Wave, received Emergency Use Authorization from the FDA, making it available for use during the crisis; New York City has already ordered 3,000 units.

In the United Kingdom, a collaboration between University College London (UCL), the UCL Hospital and the Mercedes Formula One racing team has reverse-engineered and optimized a 'continuous positive airway pressure' device. The design has been approved by UK authorities for use during the COVID-19 pandemic and made available at no cost to manufacturers and researchers. The National Health Service has ordered up to 10,000 units. And in Nigeria, Yunusa Mohammed Garba, a researcher at Gombe State University, has built a positive-pressure ventilator from hobbyist and second-hand components, for use in the northeastern Gombe state, a resource-constrained part of the country. Nigeria has a population of about 200 million, yet it might have fewer than 500 ventilators. Garba's design is currently being optimized and tested for use at the Federal Teaching Hospital Gombe, which plans to obtain two devices. "At the moment [the ventilator] can only be used in the ambulance," Garba says. "We are currently using funding from the government to build an upgraded version of the ventilator that can be fully utilized in the hospitals."

Still, even proponents of 3D printing find some of the projects potentially dangerous. "It's both inspiring and extremely scary," says Lakatos. Formlabs, for instance, investigated face-mask designs and produced numerous prototypes before recommending against 3D printing them. "The [3D-printed] face masks that I'm seeing, those designs are absolutely not sealing anything," says Lakatos. "And I think they may be even giving a false kind of confidence to people."

Following discussions with clinicians, Formlabs has instead been recommending a DIY respirator design produced by Boston Children's Hospital in Massachusetts that repurposes off-the-shelf parts, including ventilator filters and a face mask used for administering anaesthetic gas. "It seems to be a much better solution than trying to do it with 3D printing," says Lakatos.

One of the most widespread open-source face-shield designs eschews 3D printing entirely. The project began in March with the University of Wisconsin Makerspace in Madison, which worked with Midwest Prototyping, a 3D-printing company in nearby Blue Mounds, to produce them. But after bringing in Jesse Darley at the Madison office of Delve, an engineering design firm, the group decided to change tack. Instead of 3D printing, the frames and straps of the resulting 'Badger Shields' (named after the university's mascot) are made from elastic and foam that can be purchased off-the-shelf in bulk form, and cut down either by machine or by hand. Darley says such components can be made in 20 seconds, compared with several hours through 3D printing.

> "It's both inspiring and extremely scary."

The Madison group has already received orders for five million shields. To meet that demand, manufacturers have stepped in to help, including Ford Motor Company, which Darley says has tweaked the design for mass production and can make around one million shields per week.

Where credit's due

The open ethos is influencing other aspects of the pandemic response, too. More than 2,000 articles on COVID-19 have been posted in the preprint archives bioRxiv and medRxiv, according to biomed-sanity.com, a site that aggregates preprints related to the pandemic. Numerous COVID-19 data sets are available on the code-sharing site GitHub, including the data underlying Johns Hopkins University's widely used COVID-19 case-tracking dashboard. So, too, are reviews of the COVID-19 literature by researchers at the Icahn School of Medicine at Mount Sinai in New York City, and separately by a collaborative project led by computational biologists Halie Rando and Casey Greene at the University of Pennsylvania in Philadelphia.

Yet it wasn't a given that researchers would embrace openness early in the outbreak: data that are made public can be difficult to publish through conventional channels later. And multiple news reports have suggested that health workers and researchers in China were initially subjected to government limits on what information they could release. But when Chinese researchers uploaded the first genome sequence of the SARS-CoV-2 virus to the online repositories virological.org and GenBank, they opened the floodgates for more sequences from China and from the rest of the world, Hodcroft says. "I am very grateful for the scientists who took this risk, because I think this set the precedent for the rest of the epidemic." Given that the outbreak was initially confined to China, had those researchers not done so, "we might have completely different pictures that might be incorrect" she says.

Hodcroft hopes that these collaborative practices will carry over to research on other viruses and seasonal outbreaks. Not all labs have the equipment and personnel to sequence a viral genome, and even for those that do, the work requires time and money. But if more take that step — even if only every couple of weeks — she says it should be possible to track outbreaks in greater detail, using mutations as markers to better understand their geographical spread.

The pandemic could also bring lasting changes in how medical equipment is developed, produced and distributed. Lakatos would like to see hospitals have their own 3D printers as an emergency back-up to produce crucial equipment such as nasal swabs. And publicly available designs for parts such as face shields could make it easier to overcome breakdowns in international supply chains, allowing for more flexible, distributed manufacturing, says Darley.

Soon after releasing the Badger Shield plans, Darley was contacted by a company in Bonner, Montana, he had worked with that makes cycle rickshaws. The firm, called Coaster Cycles, had laid off or drastically cut hours for nearly all its workers because of the pandemic, but after seeing the open-source plans, it won a contract to supply shields to health systems spanning six US states — and hired back its workforce to produce them. Chief executive Ben Morris says the company eventually hopes to sell one million face shields. "That's the power of open source," says Darley. "It allows a family to make a few [units], or a manufacturer to make thousands, or hundreds of thousands."

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