

GOOD10

THE PANDEMIC ISSUE

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**SCIENCE
& SOCIETY**

THE ASPEN INSTITUTE

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PLACES - PHILANTHROPISTS - CELEBRITIES - WHISTLEBLOWERS - COMPANIES - MEDIA - PRODUCTS - POLITICIANS - SCIENTISTS - ACTIONS — JUNE 2020





Editors' note:

In the spirit of hope and resilience, we present *GOOD10: The Pandemic Issue*, in which we explore big-picture ways that science innovation and communication can usher in a more equitable, more progress-oriented, and safer world.

This issue is a collaboration among the science outlet *leapsmag*, the impact and engagement company GOOD, and the Aspen Institute Science & Society Program.

The GOOD10 format explores fundamental issues facing humanity through the lenses of ten forces pushing the needle toward progress: PLACES, PHILANTHROPISTS — CELEBRITIES — WHISTLEBLOWERS — COMPANIES — MEDIA — PRODUCTS — POLITICIANS — SCIENTISTS — ACTIONS. Across these categories, we seek to present unexpected and encouraging paradigms emerging from this historic crisis.

Six months after discovery of the novel coronavirus, we are beginning to see hints of what the future may hold. This edition is meant to demonstrate that even—or especially—in the face of a global calamity, creative minds across science and society are working together to overcome our world's fragility. Our vulnerabilities, both medically and economically, have always existed, but the virus brought them into sharp relief. While it may seem impossible to imagine a sunny future on the other side, we hope the enclosed collection offers a glimpse over seemingly insurmountable obstacles, revealing new horizons ahead.

Sincerely,



Aaron F. Mertz, Ph.D.

Director
Aspen Institute
Science & Society Program



Kira Peikoff, M.S.

Editor-in-Chief
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Gabriel Reilich

Editor-in-Chief
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How COVID-19 Could Usher in a New Age of Collective Drug Discovery



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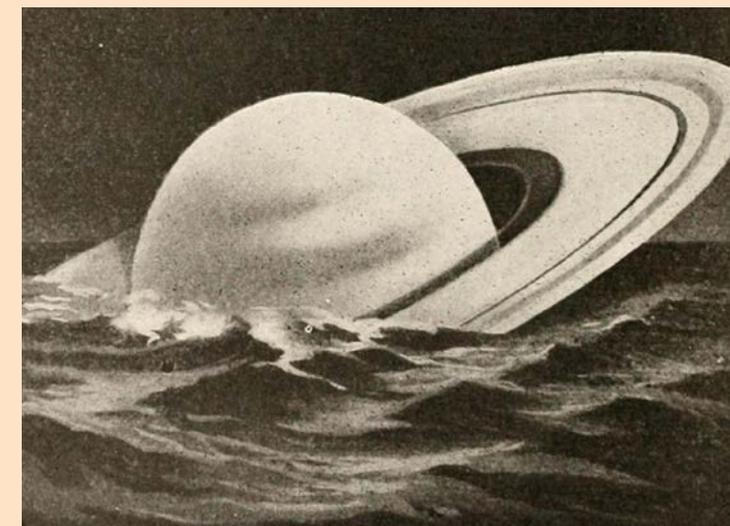
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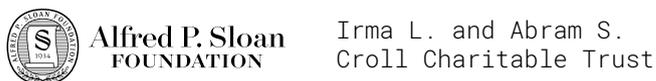
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Support for *leapsmag* comes from



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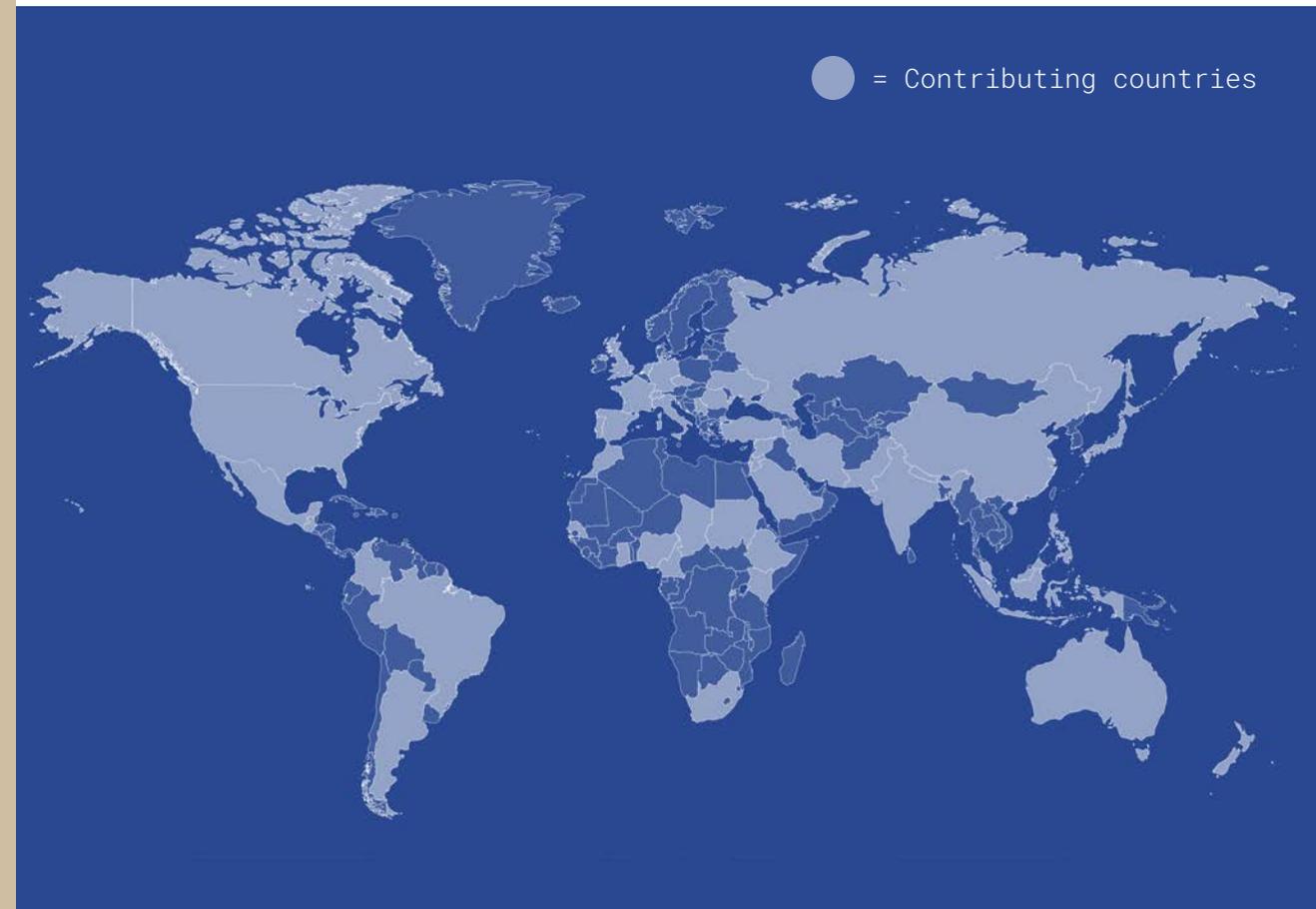


Places:

55 Lessons Learned About Science Communication Around the World

Compiled by Aaron Mertz

We collected over 50 pandemic-generated lessons in science communication from around the world from members of the Aspen Global Congress on Scientific Thinking & Action. These insights offer local experts' best practices for communicating about a global health crisis with the public in nuanced and regionally specific ways.



Senegal

Is the messenger as important as the message? Pandemics such as COVID-19 and the flood of online misinformation underlie the critical need to elevate the voices of African science leaders. African communities have talented experts they can rely on to access reliable information based on facts, if only the right platforms are provided to them. Not only do we need to share the right information and understand our target audiences, we must pay close attention to those who deliver our messages, when planning any communication strategies.

Fara Ndiaye
Deputy Executive Director,
Speak Up Africa

Brazil

The first lesson from the current pandemic for science communication in Brazil is that there is no such thing as redundancy. It doesn't matter how many times one says or explains something—about the importance of social distancing, or the uselessness of chloroquine—there is always someone you didn't reach the first time, and someone you reached but wasn't paying attention then. You have to repeat it, over and over again. Another lesson is that it actually works. Sometimes the onslaught of misinformation can make one think that the effort is futile. It isn't: if you listen carefully, you can find the results—even if only after a lot of repetition.

Natália Pasternak Taschner
President,
Instituto Questão de
Ciência (Question of
Science Institute)

Carlos Orsi
Editor-in-Chief,
Questão de Ciência
(*Question of Science*)
Magazine

Colombia

The pandemic has exposed the strengths and weaknesses of journalism, but it is also teaching, in real time, how to do good scientific journalism. In Colombia we have good results with the strengthening of our collaborative networks and working with colleagues from other countries and other media. We listen to science and give it a voice in the media. We are also looking at information from different angles. But we are left with challenges: journalists must be trained in scientific journalism, scientific journalism needs to be across all journalistic areas, and we need to learn to rigorously fact-check.

Ximena Serrano Gil
President,
Asociación Colombiana de
Periodismo Científico
(Colombian Association of
Science Journalists)

Ukraine

Ukraine started quarantine on March 25, 2020 when there were only 10 cases of COVID-19. And already on May 22 the quarantine was weakened and economic recovery began. Kyiv Mayor Vitali Klitschko's address "Don't wander the streets" worked well in the capital, the most populated city. We also managed to develop our own PCR tests within two weeks. I managed to provide comments on the origins of the new strain of coronavirus to the leaders of public opinion and it helped to prevent conspiracy theories and to stop the panic. Aspen Institute Kyiv organized a series of online events and activities to inform society about the pandemic, to help with medical supplies, and to assist the needy. In general, the COVID-19 pandemic exposed all the shortcomings and bottlenecks of the country's medical sphere. The positive outcome is that everybody learned about PCR and realized how important good science is for society.

Nataliya Shulga
CEO,
Ukrainian Science Club

New Zealand

This pandemic has highlighted how a scientific issue connects every discipline and when those from seemingly different camps work collaboratively and innovatively, a powerful alchemy can result. I think New Zealand's response to COVID-19 has shown what is possible when good science and good communication come together. We have had extraordinary leadership in this country that not only invests in science, but invests equally in the public's understanding of it. NZ citizens were brought into the process of it every single day through effective storytelling across multiple platforms. Walls between science and society melted away, and no one had to question the reasons behind what we were being asked to do to protect ourselves and each other because the science was embedded in a crystal clear story. And at the heart of that story is the message to trust in science like your life depends on it—because it does.

Gianna Savoie
Director of Filmmaking,
Center for Science
Communication,
University of Otago

Portugal

COMCEPT tries to engage with the public in person and via digital social networks. In the week before the lockdown we organized a public meeting, some style of "Skeptics in the Pub," about the new coronavirus. The speaker was the president of a medical association and presented to the public the best data available at the moment regarding SARS-CoV-2 and COVID-19. During the lockdown, we used social media to promote reliable information about the disease, shared official data from the Government, asked the public to participate in online academic studies, and debunked conspiracy theories.

João Lourenço Monteiro
Vice President,
COMCEPT: Comunidade Céptica Portuguesa
(Portuguese Skeptical Community)

Australia

Australia has ... so far ... come through the coronavirus pandemic without suffering the appalling figures seen elsewhere: Australia's death rate per million currently stands at 4, compared with 300 deaths per million in the U.S.A.; 542 in the UK; and a horrifying 800+ in Belgium. Australia is not alone in achieving such relatively low figures, but in Australia it does seem to be thanks to a fairly (but not perfect) early intervention to stop infections through border controls and lockdowns, supported by a largely cooperative public. While early communication efforts by governments were marked by contradictions and confusion, one success has been the national broadcaster, the Australian Broadcasting Corporation, in spreading factual information through a range of media platforms. In particular are the activities of Norman Swan, presenter of ABC Radio National's Health Report, who has become a key voice of coronavirus information. His daily CoronaCast podcast quickly became one of the most downloaded science podcasts around the world, and though presentations were not without dire predictions, his softly-spoken manner generally gave science communication a voice that seemed sincere and proved reliable.

Tim Mendham
Executive Officer,
Australian Skeptics

Israel

There are two salient features of the corona-related fake news in Israel: they give the reader meaning and hope. I think that if we talk more about the interface between science and moral values, we might be able to fill in the needs currently filled with prophetic, pseudo-medical, and conspiracy messages. When communicating science, a curve is not just a curve; it is also a story about solidarity.

Ayelet Baram-Tsabari
Associate Professor,
Faculty of Education in
Science and Technology,
Technion – Israel Institute
of Technology

Nigeria

COVID-19 has exposed the need to diversify the approaches and languages used to communicate science. In Science Communication Hub Nigeria and African Science Literacy Network, our scientists and fellows are using local languages to debunk science misconceptions and disinformation about COVID-19 through written articles, myth busters, and weekly webinars streamed live on Facebook and YouTube. In addition to disseminating good science, this approach has made it easier for us to understand how local communities view science and scientists, which in turn enables us to deliver content appropriate to these communities.

Mahmoud Bukar Maina
Founder,
Science Communication Hub Nigeria

Czech Republic

It is not a secret in the world of science communication that, for many, accepting the facts has little to do with facts themselves. This quiet truth has been brought out into the spotlight even more so now during the pandemic. Many of us received the lesson that we must communicate with the human first before we try communicating the science to them.

Claire Klingenberg
President,
European Council of
Skeptical Organizations
(ECSO)

U.S.A. / Mexico

The pandemic has united science communicators more than ever. It has spurred many fruitful collaborations, such as the COVID-19 Virtual Forum organized by the Mexican Network of Science Journalists with all the science communication associations in Latin America and Spain. In Mexico and the U.S., we are all fighting misinformation while keeping up to date with the freshest science, policies, and society's response. This is the time to show why science journalism is important by stepping up to the plate.

Rodrigo Pérez Ortega
Founding Member,
Mexican Network of
Science Journalists

Switzerland

Switzerland has managed to flatten the curve substantially and avoid a collapse of the public health system. Now that the country is slowly opening up again, the public discourse increasingly revolves around the question of "what was all this fuss about, when nothing happened?!" We have a term for this frustrating phenomenon: Pandemic Paradox. The successful management of outbreaks can lead to a decrease in public trust in communicators based on the perception that they were overreacting. However, we are aware of it and its origins are well studied, which gives us an assortment of tools to combat it.

Angela Bearth
Research Scientist,
Consumer Behavior,
Department of Health Sciences
and Technology,
ETH Zürich

Cameroon

The pandemic has recalled the vital role of science communication in times of crisis. Africa in general and Cameroon in particular have been spared for the moment from the catastrophe so feared by the whole world. This stems from the good collaboration among media, decision makers, and researchers who have positively influenced the apprehension of the threats by the general public as well as their behavior, which is a determining factor for the efficiency of the response.

Stéphane Kenmoe
Scientist,
Science communicator, and
television personality

Canada

Science communication is always challenging but even more so in the COVID-19 era since so much about the disease is unknown. Because of my media presence and the mandate of our Office to "demystify science for the public," I am bombarded by questions from morning to night. Unfortunately, the answers almost always have to be qualified with "ifs," "buts," and "maybes," which is not very satisfying. I think I can confidently say that self-pleasuring will not reduce the chance of contracting COVID-19 as some bloggers claim, and I can also assure people that hanging laundry on a clothesline is safe and advise them that putting the newspaper in the oven to disinfect it is a bad idea. But when questions arise about handling mail or groceries, or the effectiveness of masks, the uncertainties creep in. Then there is the issue of the numerous conspiracy theories ranging from Bill Gates's supposed plan to decimate the population to the disease being caused by 5G antennae. This puts us in a position of having to prove a negative, which is very difficult to do. My usual approach is to ask proponents questions about the number of conspirators that would have to be involved, their possible motives and the source of the information. Sometimes if you give them the rope they will hang themselves.

Joe Schwarcz
Director,
Office for Science and Society,
McGill University

India

The clamp downs, the lock downs, the prayers were all tried Lamps were lit, plates banged, and flowers were showered from skies Millions were spent, sugar pills were dispensed, grandmas soups concocted Herbs were boiled and breathing taught Alas nothing worked, they all came to naught Millions walked, hundreds died. All nation builders migrating to home villages The rulers were deaf, the nation was blind to one of the longest shut downs of its kind! But nothing worked, neither the herbs nor the sugar pills or the urine of the mother cow! 1,300 million Indians abandoned to their fate now!

Narendra Nayak
President,
Federation of Indian
Rationalist Associations

U.K. / China

COVID-19 has brought the public to witness first-hand science-in-the-making in a multi-centred world and allowed the scientific community to participate in real-time sense-making with various publics on risks and responsibilities. To borrow the term from Silvio Funtowicz, COVID-19 has ushered everyone into an era of "post-normal" science communication, in which the contents being communicated are contingent, objectives conflictual, outreach global, consequences personal, and (re)actions urgent. This further highlights the need to co-develop new approaches of transnational scientific dialogue in and with China, where public engagement is still at a nascent stage.

Joy Yueyue Zhang
Senior Lecturer in Sociology,
School of Social Policy,
Sociology, and Social Research,
University of Kent

U.S.A.

I'm inspired by the work of Avi Schiffmann, a 17-year-old high school student in Seattle, Washington, who took it upon himself to create a well-designed and up-to-do-date website for tracking COVID-19 infections and deaths from around the world. Remember when the outbreak first happened and no one could get reliable information in one place? This kid—who had been coding since he was a child—created a massive data-scraping program that allowed a centralized location for this crucial info. And it's gotten millions of views. Now that's science communication!

Lee McIntyre
Research Fellow,
Center for Philosophy
and History of Science,
Boston University

Syria

In Syria, the COVID-19 situation is messy and unclear and lacks transparency. From one side, official numbers show only 109 cases and four deaths since the outbreak; on the other side, these numbers are widely criticized by experts as well as by the public because of low testing and lack of official communication.

The nine-year-long war has hugely destroyed the medical infrastructure in Syria and pushed the majority of medical staff to leave the country. Despite these facts, the country went into only a partial lockdown and tried to minimize interactions among its population with shy measures.

The big absence in these measures was indeed “communication.” None or only a few official institutions tried to keep the population updated about the evolution of the disease inside the country. This factor pushed many civil society organizations to take over, covering topics such as self-protection, molecular biology, and pharmaceutical updates. Moreover these initiatives, mainly via Facebook, fought against misleading information such as conspiracy theories and unethical drug use. In the near future, international organizations should learn from the Syrian example and pay more attention to the impact of these volunteer-based organizations that could replace official institutions for science communication during wartime.

Mouhannad MaLeK

Founder and Chairman,
Syrian Researchers

Spain

From the skeptical movement, we noticed that at first almost everybody was very cautious, and few dared to screw it up with loose nonsense. But right away, some started placing the blame on their favorite enemy: Trump on China, China on Trump, or electromagnetic or 5G sensitivity—allied to the anti-vaccination, flat-earth, and Germanic New Medicine leagues. And then there are the crazy remedies pulled out of a hat.

Juan A. Rodríguez

Secretary,
ARP–Sociedad para
el Avance del
Pensamiento Crítico
(Society for the Advancement
of Critical Thinking);
Editor,
El Escéptico
(*The Skeptic*) magazine

Argentina / Brazil

Science communication and journalism have been reinvented in South America. More people are giving their time to contribute to science communication and are also actively engaged in teaching society how to be fact-checkers. Science popularization was reborn in small movements that spread checked news that “goes viral” through WhatsApp messages where, until then, Fake News had a clear ground. Low-cost podcasts boomed, shared sometimes even in the old way, through car loudspeakers in the street. Journalists, science communicators, and researchers became more active in professional networks. They also abandoned the practice of competing against each other, creating new ways to collaborate. Now, they share hard-to-access data through virtual meetings, pre-prints, or private communication, offering experts’ contacts and valuable advice. This is the new normal.

Roxana Tabakman

Health Writer and Science Journalist,
Red Argentina de Periodismo Científico (RADPC)
(Argentinian Network of Science Journalism);
Rede Brasileira de Jornalistas e Comunicadores
de Ciência (RedeComCiência)
(Brazilian Network of Science Journalists
and Communicators)

Japan

In Japan, the lack of outreach from scientists and science communicators during the Fukushima nuclear power plant accident following the Great East Japan Earthquake in 2011 led to a growing distrust of science professionals. In this year’s COVID-19 pandemic, many scientists are disseminating information online, and science communicators at research institutions are actively providing learning tools for children who are on standby at home. While politicians have yet to learn the importance of science communication, the public is learning how to seek out the information they need.

Masataka Watanabe

President,
Japanese Association for
Science Communication

Jordan

In these unprecedented times, building the case for science and research is of utmost priority. Therefore, at Phi Science Institute in Jordan, we aim to handle this responsibility very seriously on the regional and global levels by providing full coverage of the latest trusted scientific news in Arabic for the Arab world; turning our Research and Innovation Summit 2020 fully virtual to connect youth and experts for science from all across the region and enable them to work on joint research projects at this hard but unique time; and working with our artificial intelligence lab on healthcare A.I. products related to COVID-19.

Safa Khalaf

Community Outreach Officer,
Phi Science Institute

U.S.A.

Initial response to the outbreak in the U.S. was striking for the high degree of support for and compliance with restrictions on public activity. Scientists were centerstage in their role advising government leaders. But U.S. opinion has been shifting. There are now growing partisan divisions over the risk COVID-19 poses to public health as well as over social distancing measures aimed at slowing the spread of the disease. And, unlike years past, a partisan imprint now extends to public confidence in medical scientists to act in the public interest.

Cary Funk

Director,
Science and Society Research,
Pew Research Center

Romania

Governments all over the world have realized the importance of good communication with the public. And they have also realized the impact that false news and misinformation can have on their efforts. I work in promoting vaccination, and until now, antivaccine ideas were considered fringe and limited. The pandemic has shown that anyone can start to become a source of misinformation, and we need to combat misinformation quickly and efficiently. This lesson, hopefully, will not be forgotten.

Ovidiu Covaciu

Administrator,
Vaccinuri si Vaccinare
(Vaccines and Vaccinations);
Founder,
Coaliția România Sănătoasă
(Romania Healthy Coalition);
Producer,
Sceptici în România
(Skeptics in Romania)

Russia

Just a year ago, we launched a specialty in communication in medicine and biotechnology in our SciComm M.Sc. program. It’s been a long time coming! Like never before, we are facing the fact that science communication matters, and the lack of information only increases fears and frustrations.

Daria Denisova

Director,
Science Communication
and Outreach Office,
ITMO University

South Africa

Novel ways of sharing the science of COVID-19 with children: In South Africa (and many other countries) scientists have partnered with authors and illustrators to create a [range of storybooks, comics, and infographics](#) (in many indigenous languages) to help children understand the pandemic.

The pandemic is also an infodemic: As much as there is a need (and demand) for scientific expertise, misinformation may also flourish when people are scared and uncertain. Combating misinformation is a complex task. It is important to understand the reasons why rumours and false claims spread, and to be thoughtful and respectful when trying to correct them. [Here is some advice.](#)

Marina Joubert

Senior Researcher,
Centre for Research on
Evaluation, Science and
Technology (CREST),
Stellenbosch University

U.K.

As a researcher of so-called alternative medicine (SCAM), I should have expected it—but when it did arrive, it came as a surprise nonetheless. I am talking about the number of snake-oil salesmen putting their ugly heads above the parapet. After the pandemic had been declared, it took just days for the promotion of corona quackery to start; acupuncture, chiropractic, herbal tinctures, homeopathic remedies, colloidal silver, essential oils, dietary supplements, and many more. The entire panopticum of SCAM was on display. This was when I decided to relentlessly name and shame the villains on my blog (edzardernst.com). Today, I must have posted over 40 articles about the “corona snake-oil brigade.”

The second surprise was positive, I am glad to say. The amount of support I received was unprecedented. Hundreds of comments were posted by people who agreed that now it was more important than ever to disclose this quackery, point out what harm it does, and prevent the public from falling for it (at one stage, my humble blog was even quoted by U.S.A. Today). Many friends and colleagues joined in and wrote about SCAM merchants attempting to make a fast buck by misleading the public. But the public was far less gullible than the charlatans had hoped. My impression is that the snake-oil craze even provided a significant boost for critical thinking. The pandemic is doing untold, tragic damage, but it has also helps to explain to consumers how crucially important real science is and how devastatingly dangerous pseudoscience can be.

Edzard Ernst

Emeritus Professor,
University of Exeter

Pakistan

Pakistan is actively combating the COVID-19 pandemic by effective lock-downs. People are well aware of mask and sanitizer usage and are maintaining social distancing. Treatment of those affected is being provided by government hospitals.

Qaiser Majeed Malik

Chairman,
Pakistan Science
Foundation

Turkey

Despite strong faith in fatalism in Turkish society, trust and confidence in sciences have unexpectedly increased since the outbreak of COVID-19. Discussion programs on TV give their prime times to scientists more than governmental authorities. The Ministry of Health got more credit than any other political actors because of its daily updates on prevention arrangements. However, social media is more useful to share information about people’s corona experiences in their living environments. Personal impressions and experiences are widely circulated during the outbreak, including health conditions and daily life routines under the “stay at home” conditions. Scientific content about COVID-19 is also heavily distributed, and governmental practices are called into question by social media users frequently. Individuals become more “science citizens” both by demanding scientific information from diverse and trustworthy sources and also by producing their own content.

Çiler Dursun

Professor,
Faculty of Communication,
Ankara University,
Scientific Coordinator,
Genovate

Malaysia

A lesson I learned during the pandemic as a science communicator: it takes a crisis for the public to heed science and see it as a solution provider. Followers on my Facebook page increased by more than 2,000; subscription to my newspaper, The Petri Dish, increased among the public; and more media interviews. How can we sustain this appetite for science? Highlight the WHY more than the HOW and WHAT.

Mahaletchumy Arujanan

Executive Director,
Malaysian Biotechnology
Information Centre (MABIC)

Germany

The brief guide on [Proper Criticism](#) by psychology professor Ray Hyman has been crucial for effective science communication, where he explains essential points, such as not going beyond your level of competence and using the principle of charity. Beyond presenting the facts and the science, which are often later forgotten by the audience, people remember the messenger. We have learned that coming across as compassionate, credible and trustworthy gives the message a far more significant and lasting impact.

Amardeo Sarma

Chair,
Gesellschaft zur
wissenschaftlichen
Untersuchung von
Parawissenschaften
(Society for the
Scientific Investigation
of Parasciences)

Netherlands

In the early phase of the pandemic in the Netherlands, the government opted for a moderately strict lockdown and suggested that in this way the virus that was still present would lead to herd immunity. There was massive outrage because the public understood that civilians were being sacrificed for the creation of this herd immunity. When the government subsequently explained that the creation of herd immunity was not the goal of its policy but a welcome side effect, the unrest subsided.

Cees Renckens

Chair,
Vereniging tegen
de Kwakzalverij
(Dutch Society
Against Quackery)

Rwanda

At the University of Global Health Equity (UGHE), we have worked to further our educational mission during this unprecedented challenge of COVID-19, a pandemic that reminds us of the critical importance of our mission. With our campus located in the rural north of Rwanda, it was our priority to not only continue to provide quality education—which has transitioned to fully virtual learning—but also to take extensive precautions to protect our students, staff, faculty, and the surrounding community from the virus. Given the toll of this virus and the drastic change in social norms it has created, we are conducting not only weekly physical screenings but also mental health screenings. We are grateful to report that all from our UGHE community have remained in strong health. We are grateful to keep contributing to the fight for global health equity during a time such as this.

Agnes Binagwaho
Vice Chancellor,
University of Global
Health Equity;
former Minister of Health

U.S.A.

The pandemic has revealed that now more than ever, science communication cannot prevail until nations and states dismantle the underlying structural injustices that erode trust in science. For instance, the exploitation of racial minorities' justified distrust of the medical establishment by anti-vaccine groups has become a matter of growing concern—from the 2017 Minnesota measles outbreak after activists convinced Somali-American immigrants that vaccines cause autism to the growing present-day opposition to a COVID-19 vaccine. Still, there is hope if only those who disseminate science-based information understand that the anti-vaccine movement, and similar movements that sit at the crossroads of science and society, have never been fundamentally about evidence. It's about whom to trust.

Kavin Senapathy
Science, health, and parenting writer;
Member,
American Society of Journalists and Authors;
Contributing Editor,
SciMoms.com

Indonesia

Although the clerics all agreed that public prayer should be banned to slow the spread of the disease, many Indonesian Muslims clogged the mosque during Ramadan and Eid, completely ignoring the health and religious authorities. Some Indonesian Muslims even strongly believe that somehow the Jewish and the Chinese are the masterminds of the pandemic—a bizarre claim that Muhammadiyah, one of the largest Muslim organizations, is trying hard to debunk. Conspiracy-theory believers are still not completely convinced by counter-arguments coming from religious authorities.

Rizqy Amelia Zein
Assistant Professor,
Department of Personality
and Social Psychology,
Universitas Airlangga

U.S.A.

I practice Stoic philosophy and have been wondering what the Stoics might have to say about how to react to a pandemic. It struck me that our current situation is somewhat analogous to something many in the ancient world had to experience: exile. When someone is in exile, their life is very different, of lower quality, and far more constrained, than what they are used to. Just like during self-isolation or lockdown in a pandemic.

So what did the Stoics do when in exile? They taught philosophy to others, like Musonius Rufus, a famous first-century teacher. And they wrote letters of consolation to their loved ones, as Seneca, also in the first century, did to his mother Helvia.

In that letter, Seneca says that Fortune comes and goes, but what remains constant, and independent of Fortune, is our character, our determination to always be the best human beings we can be. Indeed, it is in times of difficulties and setbacks that we have an opportunity to shine. As he puts it, everyone is a good pilot when the sea is calm. It's only in the midst of a storm that we see who is truly skilled. So let's think of the current storm as an opportunity to improve our proficiency at navigating life.

Massimo Pigliucci
Professor of Philosophy,
City College and the
Graduate Center,
City University of New York

Morocco

Our communication efforts have included webinars on the environment, climate change, and inter-linkages with the pandemic, for example effects of coronavirus on biodiversity, how COVID-19 has benefited climate, and the green economic recovery from COVID-19. Our members have also written opinion articles published in journals and media in more than ten Arab countries. These activities have attracted the attention of communities, raised awareness as the scientific material was communicated in the Arabic language, and significantly unleashed the potential of our members.

Hajar Khamlichi
President and Co-Founder,
Mediterranean Youth Climate Network;
Board Member,
Moroccan Alliance for Climate and
Sustainable Development

Iran

Iran was one of the first countries to be involved in the crisis. Widespread international sanctions have restricted the capability to control the virus. In response to the pandemic, scientific institutions, non-governmental organizations, and government agencies have facilitated the transition from this crisis by:

- Closing religious places (e.g., shrines, mosques) and pivoting their activities, in some cases as a temporary production workshops for masks and medical equipment;

- Expanding the penetration rate of state and free internet throughout the country;

- Increasing the presence of scientists in the mass media to raise public awareness and help control the disease;

- Supporting online entertainment platforms by the Ministry of Information of Communications and Technology in cooperation with other ministries, including the Ministry of Culture and Islamic Guidance and the Cultural Heritage Organization, to run virtual museum tour platforms, hold online music concerts, etc.; and

- Launching the #BeScientific campaign (in Persian) as a collaboration between the UNESCO Chair on Popularization of Science at the National Research Institute for Science Policy (NRISP) and the Iranian Association for the Popularization of Science, with the aims to enlighten public opinion and fight pseudo-science and fake news related to COVID-19.

Akram Ghadimi
Associate Professor,
Department of Popularization
of Science,
National Research Institute
for Science Policy

Philippines

Here in the Philippines, government agencies regularly post pandemic-related visual aids through social media in order to prove a point (e.g., “The curve is flattening.” “We have more or fewer cases”), except the visual aids are unintuitive, if not altogether cherry-picked: Trend lines are traced haphazardly, bar charts are not drawn to scale, and government spokespersons almost literally tell people what to believe. Instead of just mocking these visual aids, younger data scientists and statisticians have taken to social media to talk about how to interpret data and why some visual aids are badly made. These scientists use these social media posts as a starting point to help people think critically rather than accept knowledge wholesale, which fits well with how the practice of science is about questioning, critical thinking, and healthy skepticism.

Inez Ponce de Leon
Assistant Professor,
Department of Communication,
Ateneo de Manila University

U.S.A. / Colombia

Seven years ago, I wrote a book in Spanish called *Un enemigo invisible / An Invisible Enemy*. This science and adventure novel for young adults is read in several schools throughout Colombia. The plot deals with a deadly virus that gets into Miami via a howler monkey brought from Guyana in a shipment of wild monkeys for lab research. The monkey is a reservoir (whose original host is a bat) of the (fictitious) virus Canzanboria, which infects one of the young main characters. The book thus becomes a race to find out what this virus is, where it comes from, how to get a vaccine, and how to stop it—like what is happening now.

The exciting part is that, because of the pandemic, several schools are hosting videoconferences where I can talk to kids about the book and my behind-the-scenes work with real-life virus hunters—research I did in order to write the novel. These kids are hugely interested and love my explanations about the evolution of viruses, the roles they play in our life, and the fact that were it not for a virus, none of us mammals would exist.

This pandemic has opened a window for me to take the scientific process to young minds in often inaccessible places in Colombia, as well as in China (the book was translated into Mandarin). I think reaching young people is the way to achieve a well-educated and interested society that will eventually grow up to support science in a meaningful way.

Ángela Posada-Swofford
Science, environment,
and exploration journalist,
lecturer, moderator,
and book author;
Board Member,
Colombian Association of
Science Journalists

Ghana

Shortly after the first case was reported, various professional science societies and associations came together to form a COVID response team. The purpose was simple: to coordinate availability of scientists for media engagements. It worked well and continues to do so, making sure that people remain informed based on accurate science. It has been a lesson on coming together and communicating science collaboratively.

Thomas Tagoe
Lecturer,
Physiology and
Pharmacology,
University of Ghana;
Co-Founder,
GhScientific

Nepal

In order to control the rate of proliferation of COVID-19, social distancing has been a globally accepted effective method. In order to maintain such distancing and yet continue our business as usual, information and communication technology available today is very much useful. Also, mobile technology has been easily accessible even to people living in poverty in Nepal. Therefore, we can take the widespread use of internet platforms such as Skype, Facebook, Zoom, MS Teams, Voov, WhatsApp, Kakao, Viber, WeChat, etc. for any kind of communication including for science teaching, seminars, conferences, meetings, and discussions.

Sunil Babu Shrestha
Vice-Chancellor,
Nepal Academy of Science and Technology (NAST)

Guatemala / U.S.A.

At the Cornell Alliance for Science, we are currently highlighting how science is being used to fight COVID-19 and dispelling myths through our online platform. In Guatemala, there have been different spaces created for “science innovation” to address the challenges this pandemic brings with communication strategies that include hashtags such as #nuestrascienciaresponde (our science has answers) and #cienciaGTenaccion [GT (Guatemala) science in action]. However, there is also a lot of misinformation spread through the many social media platforms used in the country. We believe we can amplify projects that bring attention to how science is pivotal in a crisis and, at the same time, dispel misinformation by circulating fact-checked pieces in Spanish for our Central American audiences.

Pablo Ivan Orozco
Policy Affairs Associate,
Cornell Alliance for Science

France

During this pandemic, perhaps most confusing of all has been the unexpected ideological struggle on the fundamentals of medicine. While evidence-based medicine was demonstrating its power, a discourse combining postmodernism and medieval thinking was developing “against the method,” celebrating “common sense” medicine as opposed to medicine presented as big data and big pharma.

France found itself, with its “Marseille Protocol” at the center of this tornado whose effects were felt as far as the U.S.A.–Brazil axis. At the heart of the turmoil, the French Association for Scientific Information has endeavoured to communicate daily on its public website and its internal forum the reliable sources of information enabling everyone to untangle scientific facts from unfounded rumours, to understand where the established knowledge is and where the uncertainties lie, and to remind people that medicine is not a game of poker.

Michel Naud
Director and
Former President,
Association Française pour
l'Information Scientifique
(French Association for
Scientific Information)

Serbia

During the COVID-19 pandemic, the Center for the Promotion of Science was active in raising citizens' awareness of the challenges they faced. Very early on, at the end of March, the Serbian translation of the extensive database was published on the Center's portal, enabling citizens to find out what is really behind the often confusing statistics that the media conveyed to the public in a clumsy and sometimes distorted manner. In early June, a new issue of the Center's popular science magazine *Elementi* was released. In a special segment containing six articles accompanied by appropriate visual storytelling, eminent physicians, philosophers, data scientists, science journalists, and graphic designers addressed some important topics related to the pandemic, such as the evolution of SARS-CoV-2, data modeling, mental health of physicians and citizens, and the moral challenges with which decision-makers were faced.

Ivan Umelji

Head of the Department for Publishing and Media Production, Centar za Promociju Nauke (Center for the Promotion of Science)

Marko Krstić

Acting Director, Centar za Promociju Nauke (Center for the Promotion of Science)

U.S.A. / U.K.

At Annual Reviews, we removed access control to all of our content—everything that we have published in the past 88 years—on March 13, 2020 in response to the COVID-19 pandemic. Compared to April 2019, usage of the content in April 2020 increased more than threefold (to 3.1 million downloads worldwide). It was not just our virology and public-health related content that was read more—every field from astronomy to vision science saw a substantial uptick. Removing barriers to access reveals the breadth interest in science for the public good; in the U.S., 28 different city governments, 18 state governments, the U.S. Department of Justice, the U.S. Senate, and the U.S. House of Representatives all recorded usage, as did parliaments in scores of other countries. Strikingly, access from less wealthy nations rose dramatically; for example, Morocco by 1,403 percent (from 229 downloads in April 201 to 3,444 in April 2020), Sri Lanka by 1,523 percent (260 in April 2019 to 4,545 in April 2020), and Ecuador by 1,033 percent (273 in April 2019 to 3,094 in April 2020). This usage re-emphasizes the value of democratizing access to science across all disciplines (not just COVID-19) and parts of the world.

While the great majority appreciate their personal and public duty to reduce the chance of infection, in the face of weeks of isolation and economic hardship, many people experience angst, anger, and disbelief. Using science to help people understand the dissonances that they were experiencing, and the necessity of their sacrifice, we developed a free service called *Pandemic Life* as a way to relate the body of social science research to the COVID-19 pandemic. Several times a week, articles that offer insights into such matters as the benefits of social norms, how to guide children's development, dealing with isolation, and the nature of happiness are covered on social media and in a short news story, and the relevant review article is made available for a deeper dive. This evolved into a series of online conversations called *Pandemic Live*, during which some of the world's foremost researchers discuss and answer questions on aspects of the pandemic. Directly connecting the public with researchers in ways that go beyond sound bites and political posturing provides a powerful way to communicate reliable science insights into health, social, and economic issues in an age of misinformation.

Richard Gallagher

President & Editor-in-Chief, Annual Reviews, Publisher, *Knowable Magazine*

Russia

The experience of the South Korean church spreading coronavirus has not taught us—in Russia—anything. There have been large masses of people standing in line in the Kazan Cathedral to kiss the remains of a dead saint. A number of Russian Orthodox priests have commented that you cannot catch a virus in church. The head of church public communications has stated that people should avoid massive gatherings—but religious gatherings are an exception. In the Vatican, Pope Francis was a welcome contrast, giving Easter mass behind closed doors and praying in an empty St. Peter's Square, showing by example the distancing and isolation to which we must adhere in order to save lives. Unfortunately, the Russian Orthodox church does not have such concerns for the people.

Alexander Panchin

Senior Researcher
Institute for Information Transmission Problems
(Kharkevich Institute)
Member
Commission on Pseudoscience and Research Fraud
Russian Academy of Sciences

India

The clamp downs, the lock downs,
the prayers were all tried
Lamps were lit, plates banged, and
flowers were showered from skies
Millions were spent, sugar pills were
dispensed, grandmas soups concocted
Herbs were boiled and breathing taught
Alas nothing worked, they all came to
naught
Millions walked, hundreds died.
All nation builders migrating to home
villages
The rulers were deaf, the nation was
blind
To one of the longest shut downs
of its kind!
But nothing worked, neither the herbs
nor the sugar pills or the urine of the
mother cow!
1,300 million Indians abandoned to their
fate now!

Narendra Nayak

President,
Federation of Indian
Rationalist Associations

U.S.A.

Vaccination has fallen dramatically in the U.S. since the World Health Organization declared a pandemic. One proposal is to use gain-framed messages. This idea builds on insights from prospect theory, which was developed by Nobel laureate Daniel Kahneman. The theory suggests that prevention and treatment behaviors are motivated better by messages with a gain than a loss frame. As applied to our current crisis, the idea is to focus on the benefits of vaccination and on doctors' offices as being safe places. Many of us know more about what our grocery store is doing to keep us safe than what our doctor is doing. Proactively addressing this can help get vaccination back on track.

Noel Brewer

Professor,
Department of
Health Behavior,
Gillings School of
Global Public Health,
University of
North Carolina,
Chapel Hill

Ethiopia

In Ethiopia, there are difficulties with governments, stakeholders, and the biomedical community regarding how media should further COVID-19 education and prevention. On March 27, 2020, the Ethiopian Ministry of Health and Ministry of Technology Innovation announced that Ethiopia made significant progress toward development of a cure for the virus: "In collaboration with Ethiopian traditional doctors and modern science research and clinical doctors, we are exploiting our indigenous and traditional knowledge and shaping it into modern science procedures to prepare a cure for COVID-19. The medicine has potential to prevent the virus, is non-poisonous, and is promising." Following this announcement, many maverick and dissident scientists opposed the statement and said it was premature to make an announcement before a clinical trial was started and that it distracts people's attitudes from vigilance and alertness against the pandemic and politicizes the situation. The majority of Ethiopian people agree: a poll conducted through the messaging platform Telegram found that 71% of people said it was incorrect to make such an announcement before a clinical trial.

Tenaw Terefe

Assistant Professor,
Faculty of Journalism
and Communication,
Addis Ababa University

Italy

As fake news and conspiracy theories about the coronavirus piled up every single day during lockdown, I found myself, as many other science popularizers here in Italy did, with an urge to share—with those following us on social media—analysis, critical thinking skills, and tools to overcome the craze and better understand what was happening.

Day after day, I noticed a closer bond developing with more and more people. They were not only asking the "expert" for information or insights in clearing up some new absurd claim, but they were also looking for some kind and reassuring words from someone they now perceived as a calm and rational friend, someone who could take even the wildest fears back down to earth.

Eventually, as things started to get a little easier and those who could returned to their jobs, crazier claims lost their grip, but the bond of trust between us, pop science talkers, and our audience, not only is still there, but has grown stronger. And it looks like a lot of good and promising things can come out of this.

Massimo Polidoro

Executive Director,
Comitato Italiano per il
Controllo delle Affermazioni
sul paranormale (Italian Com-
mittee for the
Investigation of Claims on
the Paranormal)

Saudi Arabia

The infodemic we're currently seeing alerted me to a crucial point: the correct, reliable, and verified scientific information and evidence is widely available to all those who seek it.

In our digital age, the root cause of ignorance cannot be limited to only knowledge scarcity. A century ago, illiteracy was prevalent in the majority of the global population, and knowledge was only available to a small group of society. All of that has changed, but ignorance still prevails. The root causes must be deeper and broader.

I reckon that this particular ignorance is rooted in the wrong understanding of the scientific methodology process (making an observation, formalizing a hypothesis, experimenting, gathering data, analyzing it, and building a theory). The overwhelming majority of conspiracy theorists' arguments are based on a misconception of one of these basic principles, whether by confusing hypothesis for a theory, or lack of familiarity with methods of constructing a solid experiment, or ways of examining data and evidence, or erroneous analysis of experiments' results outside their scientific context.

Assuming the validity of this observation, the answer to all the ongoing "scientific" controversies won't be by discussing each issue separately, but by referring back to the basics of the scientific methodology, and determining the cognitive origins of this collective fault and reforming it.

Unfortunately, schools do not pay as much attention to the methodology as it deserves, but consider it as another lesson that must be finished to complete the curriculum. This has contributed to the emergence of many strange beliefs in our society without the slightest evidence or collective scrutiny. It is our role as science communicators to bring back the central role of the scientific methodology and reeducate the public about its importance and applications in our daily lives.

Faris Bukhamsin

CEO,
Scientific Saudi

U.S.A. / India

Calling out scientific misinformation explicitly is critical for effective science communication. This can be an arduous task since misinformation can be generated rapidly (and at low cost!) through internet platforms. A group of scientists from top research institutes in India (the Tata Institute for Fundamental Research, Mumbai and the Indian Institute of Science, Bangalore) have set up a website with "Hoax Busters" that contains simple infographics explicitly calling out misinformation circulating in social media. This is a critical tool for science communication in a country like India where scientific literacy remains low but technology access has increased significantly (over 500 million smartphone users), leading to an explosion in the circulation of misinformation.

Abhilash Mishra

Director,
Kevin Xu Initiative
on Science, Technology,
and Global Development,
University of Chicago

Kenya

The Kenyan Government has been consistent in providing status updates with three key messages, while keeping communication short and simple:

1. Wash hands regularly with soap and sanitize often,
2. Social distancing, and
3. Wear face masks.

One other lesson is use of spokespersons trusted by communities such as faith-based leaders and local administration (not as widely, but at least this is a positive).

Margaret Karembu

Director,
International Service
for the Acquisition of
Agri-biotech Applications
(ISAAA)
AfriCenter

Chad

This pandemic has shown us that we have an intimate relationship with nature and that there is an urgent need to enhance biodiversity protection. Biodiversity is a protection against the development of pandemics, and nature is our pharmacy and provides the molecules needed for both modern and traditional knowledge. Indigenous peoples have known this for centuries, living in harmony with nature, and advocating for a paradigm shift in our relationship to the environment. My hope is that this crisis will be a wake-up call for all of us. COVID-19 has demonstrated that politicians and business leaders are lost without science, and that listening to scientists can save lives.

Hindou Oumarou Ibrahim

Coordinator,
Association des Femmes Peules
Autochtones du Tchad (AFPAT)
(Association of Peul Women and
Autochthonous Peoples of Chad)

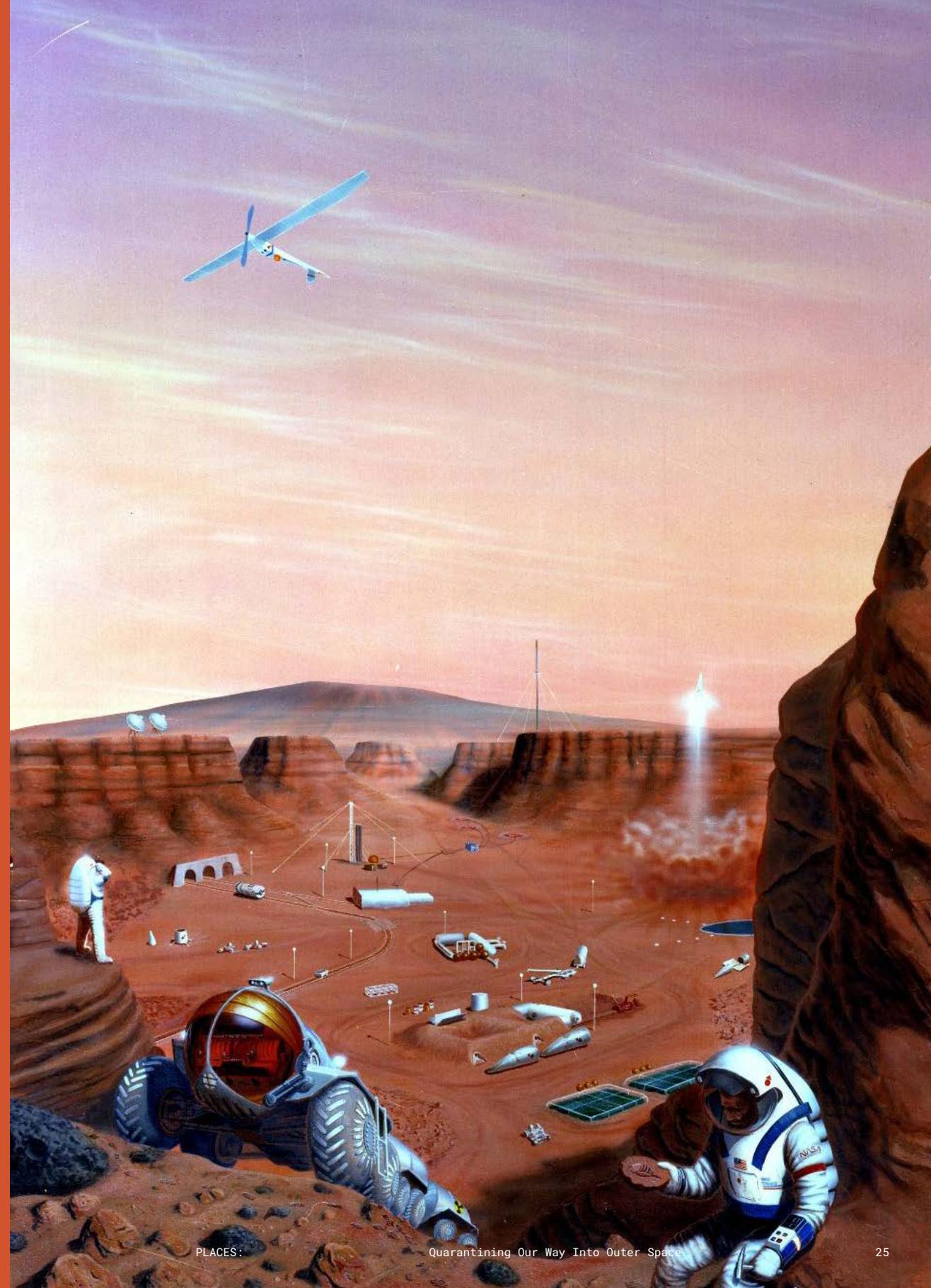
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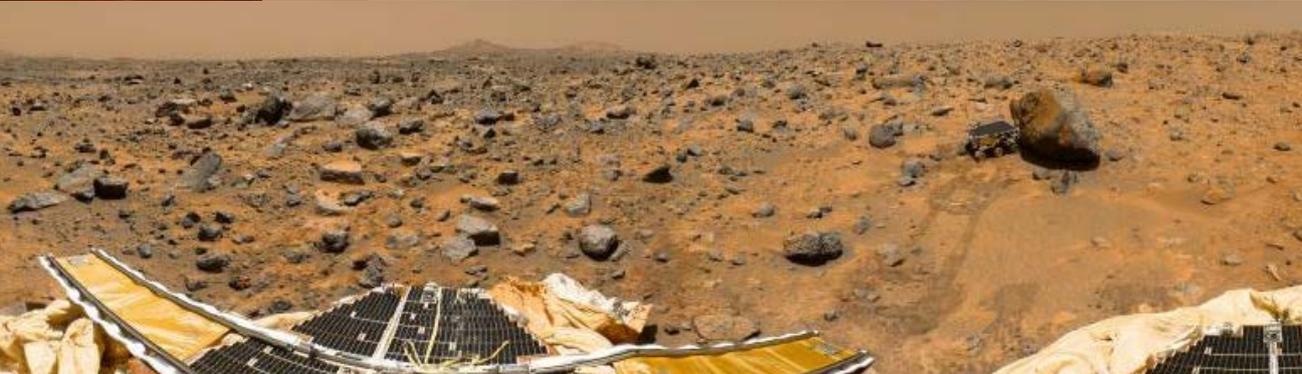


Places:

Quarantining Our Way Into Outer Space

By Damon Brown





Social isolation. Strange pathogens outside. Strategic resource planning. Our Earthbound pandemic-driven social distancing could be mistaken for adapting to another, foreign planet. After all, we're donning all our protective apparel to go on an airplane or to the grocery store, nevertheless to just open our front door. Perhaps this is training for the world galactic visionaries Elon Musk, Jeff Bezos, and Richard Branson see in our future.

Ready to go live on Mars or something? Not so fast, experts say. The experience of shelter in place isn't parallel to being a space settler, or even an astronaut.

"Certain aspects are similar, but still, honestly, there are too many differences to say it preps us," says Angelo Vermeulen, co-founder of the art-science collective SEADS (Space Ecologies Art and Design) Network. In 2013, he served as a NASA crew commander for a four-month Mars-on-Earth mission, isolated in a geometric biodome with five others. "There are parallels to the individual psychological experience, but from an operational standpoint, it is too different. You don't need a spacesuit, aren't threatened by a thin atmosphere or worried about being overpowered by radiation."

Outside threats aside, we have a bigger experience gap: Most of us didn't see this pandemic coming and weren't trained to survive the current new normal. NASA astronauts get at least two years of basic training. We received none. Intergalactic explorers understand gravity, air pressure, and other important

criteria based on decades of space knowledge. Alternatively, new novel coronavirus data is coming in real time, changing the threats, precautions, and needs dramatically. Things feel a little different when you're winging it.

Lastly, with respect to Apollo 13, space travelers have a timeline for when their experience will be over. There are mishaps, challenges and adjustments, but every well-supported journey person leaves Earth with an agenda (and a team back home to help keep them on track).

The pandemic, on the other hand, has no definitive end. It is unclear when a reliable vaccine will be readily available. It is also not known how long we should shelter-in-place, as pulling the trigger too early could bring another wave of illness. We are missing definitive milestones, which, Vermeulen says, would make our isolation experience easier to navigate. "When you're on a mission, the end date is always on the horizon. You can celebrate the midpoint and check off major milestones, which helps."

Also, unlike a kid pretending to be in a rocket, most of us didn't dream of one day being socially isolated for an indeterminate amount of time. "If you're ambitious and working in the field, then it is your goal in life to experience [space and the related isolation]," he says. "With the pandemic, though, nobody chose to do this." ■

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*Entrepreneur and business coach **Damon Brown** is the author of several best-selling books. His latest title is **Bring Your Worth: Level Up Your Creative Power, Value & Service to the World.***

2



Philanthropists:

An Exclusive Interview with Wendy Schmidt about Science in the Pandemic Era

WENDY SCHMIDT is a philanthropist and investor who has spent more than a dozen years creating innovative non-profit organizations to solve pressing global environmental and human rights issues. Recognizing the human dependence on sustaining and protecting our planet and its people, Wendy has built organizations that work to educate and advance an understanding of the critical interconnectivity between the land and the sea. Through a combination of grants and investments, Wendy's philanthropic work supports research and science, community organizations, promising leaders, and the development of innovative technologies. Wendy is president of The Schmidt Family Foundation, which she co-founded with her husband Eric in 2006. They also co-founded Schmidt Ocean Institute and Schmidt Futures.

By Kira Peikoff and Aaron Mertz



Editors: The pandemic has altered the course of human history and the nature of our daily lives in equal measure. How has it affected the focus of your philanthropy across your organizations? Have any aspects of the crisis in particular been especially galvanizing as you considered where to concentrate your efforts?

Wendy: The COVID-19 pandemic has made the work of our philanthropy more relevant than ever. If anything, the circumstances of this time have validated the focus we have had for nearly 15 years. We support the need for universal access to clean, renewable energy, healthy food systems, and the dignity of human labor and self-determination in a world of interconnected living systems on land and in the Ocean we are only beginning to understand.

When you consider the disproportionate impact of the COVID-19 virus on people who are poorly paid, poorly housed, with poor nutrition and health care, and exposed to unsafe conditions in the workplace—you see clearly how the systems that have been defining how we live, what we eat, who gets healthcare and what impacts the environment around us—need to change.

If the pandemic teaches us anything, we learn what resilience looks like, and the essential role for local small businesses including restaurants, farms and ranches, dairies and fish markets in the long term vitality of communities. There is resonance, local economic benefit, and also accountability in these smaller systems, with shorter supply chains and less vertical integration.

The consolidation of vertically integrated business operations for the sake of global efficiency reveals its essential weakness when supply chains break down and the failure to encourage local economic centers leads to intense systemic disruption and the possibility of collapse.

Editors: For scientists, one significant challenge has been figuring out how to continue research, if at all, during this time of isolation and distancing. Yet, your research vessel Falkor, of the Schmidt Ocean Institute, is still on its expedition exploring the Coral Sea Marine Park in Australia—except now there are

no scientists onboard. What was the vessel up to before the pandemic hit? Can you tell us more about how they are continuing to conduct research from afar now and how that's going?

Wendy: We have been extremely fortunate at Schmidt Ocean Institute. When the pandemic hit in March, our research vessel, Falkor, was already months into a year-long program to research unexplored deep sea canyons around Australia and at the Great Barrier Reef. We were at sea, with an Australian science group aboard, carrying on with our mission of exploration, discovery and communication, when we happened upon what we believe to be the world's longest animal—a siphonophore about 150 feet long, spiraling out at a depth of about 2100 feet at the end of a deeper dive in the Ningaloo Canyon off Western Australia. It was the kind of wondrous creature we find so often when we conduct ROV dives in the world's Ocean.

For more than two months this year, Falkor was reportedly the only research vessel in the world carrying on active research at sea. Once we were able to dock and return the science party to shore, we resumed our program at sea offering a scheduled set of now land-based scientists in lockdown in Australia the opportunity to conduct research remotely, taking advantage of the vessel's ship to shore communications, high resolution cameras and live streaming video. It's a whole new world, and quite wonderful in its own way.

Editors: Normally, 10–15 scientists would be aboard such a vessel. Is “remote research” via advanced video technology here to stay? Are there any upsides to this “new normal”?

Wendy: Like all things pandemic, remote research is an adaptation for what would normally occur. Since we are putting safety of the crew and guest scientists at the forefront, we're working to build strong remote connections between our crew, land based scientists and the many robotic tools on board Falkor. There's no substitute for in person work, but what we've developed during the current cruise is a pretty good and productive alternative in a crisis. And what's important is that this critical scientific research into the deep sea is able to continue, despite the pandemic on land.





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Editors: Speaking of marine expeditions, you've sponsored two XPRIZE competitions focused on ocean health. Do you think challenge prizes could fill gaps of the global COVID-19 response, for example, to manufacture more testing kits, accelerate the delivery of PPE, or incentivize other areas of need?

Wendy: One challenge we are currently facing is that innovations don't have the funding pathway to scale, so promising ideas by entrepreneurs, researchers, and even major companies are being developed too slowly. Challenge prizes help raise awareness for problems we are trying to solve and attract new people to help solve those problems by giving them a pathway to contribute.

One idea might be for philanthropy to pair prizes and challenges with an "advanced market commitment" where the government commits to a purchase order for the innovation if it meets a certain test. That could be deeply impactful for areas like PPE and the production of testing kits.

Editors: COVID-19 testing, especially, has been sorely needed, here in the U.S. and in developing countries as well as low-income communities. That's why we're so intrigued by your Schmidt Science Fellows grantee Hal Holmes and his work to repurpose a new DNA technology to create a portable, mobile test for COVID-19. Can you tell us about that work and how you are supporting it?

Wendy: Our work with Conservation X Labs began years ago when our foundation was the first to support their efforts to develop a handheld DNA barcode sensor to help detect illegally imported and mislabeled seafood and timber products. The device was developed by Hal Holmes, who became one of our Schmidt Science Fellows and is the technical lead on the project, working closely with Conservation X Labs co-founders Alex Deghan and Paul Bunje. Now, with COVID-19, Hal and team have worked with another Schmidt Science Fellow, Fahim Farzardfar, to repurpose the technology—which requires no continuous power source, special training, or a lab—to serve as a mobile testing device for the virus.

The work is going very well, manufacturing is being organized, and distribution agreements with hospitals and government



agencies are underway. You could see this device in use within a few months and have testing results within hours instead of days. It could be especially useful in low-income communities and developing countries where access to testing is challenging.

Editors: How is Schmidt Futures involved in the development of information platforms that will offer productive solutions?

Wendy: In addition to the work I've mentioned, we've also funded the development of tech-enabled tools that can help the medical community be better prepared for the ongoing spike of COVID cases. For example, we funded EdX and Learning Agency to develop an online training to help increase the number of medical professionals who can operate ventilators. The first course is being offered by Harvard University, and so far, over 220,000 medical professionals have enrolled. We have also invested in informational platforms that make it easier to contain the spread of the disease, such as our work with Recidiviz to model the impact of COVID-19 in prisons and outline policy steps states could take to limit the spread.

Information platforms can also play a big part pushing forward scientific research into the virus. For example, we've funded the UC Santa Cruz Virus Browser, which allows researchers to examine each piece of the virus and see the proteins it creates, the interactions in the host cell, and — most importantly — almost everything the recent scientific literature has to say about that stretch of the molecule.

Editors: The scale of research collaboration and the speed of innovation today seem unprecedented. The whole science world has turned its attention to combating the pandemic. What positive big-picture trends do you think or hope will persist once the crisis eventually abates?

Wendy: As in many areas, the COVID crisis has accelerated trends in the scientific world that were already well underway. For instance, this moment has propelled broad movements toward open publication and open sharing of data and samples—something that has always been a core belief in how we support and advance science.

We believe collaboration is an essential ingredient for progress in all areas. Early in this pandemic, Schmidt Futures held a virtual gathering of 160 people across 70 organizations in philanthropy, government, and business interested in accelerating research and response to the virus, and thought at the time, it's pretty amazing this kind of thing doesn't go all the time. We are obviously going to go farther together than on our own...My husband, Eric, has observed that in the past two months, we've all catapulted 10 years forward in our use of technology, so there are trends already underway that are likely accelerated and will become part of the fabric of the post-COVID world—like working remotely; online learning; increased online shopping, even for groceries; telemedicine; increasing use of AI to create smarter delivery systems for healthcare and many other applications in a world that has grown more virtual overnight.

We fully expect these trends to continue and expand across the sciences, sped up by the pressures of the health crisis. Schmidt Ocean Institute and Schmidt Futures have been pressing in these directions for years, so we are pleased to see the expansions that should help more scientists work productively, together.

Editors: Trying to find the good amid a horrible crisis, are there any other new horizons in science, philanthropy, and/or your own work that could transform our world for the better that you'd like to share?

Wendy: Our deepest hope is that out of these alarming and uncertain times will come a renewed appreciation for the tools of science, as they help humans to navigate a world of interconnected living systems, of which viruses are a large part. The more we investigate the Ocean, the more we look deeply into what lies in our soils and beneath them, the more we realize we do not know, and moreover, how vulnerable humanity is to the forces of the natural world.

Philanthropy has an important role to play in influencing how people perceive our place in the world and understand the impact of human activity on the rest of the planet. I believe it's philanthropy's role to take risks, to invest early in innovative technologies, to lead where governments and industry aren't ready to go yet. We're fortunate at this time to be able



to help those working on tools to better diagnose and treat the virus, and to invest in those working to improve information systems, so citizens and policy makers can make better decisions that can reduce impacts on families and institutions.

From all we know, this isn't likely to be the last pandemic the world will see.

It's been said that a crisis comes before change, and we would hope that we can play a role in furthering the work to build systems that are resilient—in information, energy, agriculture and in all the ways we work, recreate, and use the precious resources of our planet. ■

3



Celebrities:
Neil deGrasse Tyson Wants Celebrities to Promote Scientists

By Amy Odell



“P

resident Kennedy was the first president to not wear a hat. Have you seen men wearing hats since then?” Neil deGrasse Tyson, one of the world’s few astrophysicists with a household name, asks on the phone from his car. Well, no. “If I wear some cowboy hats, it’s because it’s the outfit, it’s not because that’s my standard equipment when I leave the home.”

But Tyson, who speaks in methodically reasoned paragraphs with lots of semi-rhetorical questions to make sure we’re all still listening, isn’t really making a point about Mad Men-era men’s clothing trends. “Should a president influence fashion?” he says. “I think people sometimes don’t know the full power they have over other people. So, that’s the first prong in this comment. My second prong is, why would anyone take medical advice from a politician?”

Days before our conversation, news broke that President Trump said he was taking hydroxychloroquine, which he had hyped for months as a surefire magical cure for COVID-19 — the science just hadn’t caught up to his predictions. But the science never did catch up; instead, it went the opposite direction, showing that hydroxychloroquine, when used to treat COVID-19 patients, actually led to an increased risk of death.

Alarm spread swiftly around the globe as experts cast the president’s professed self-medicating as illogical and dangerous. However, it was just one of a series of wild pieces of medical advice espoused by Trump from his mighty pulpit, like that, hey, maybe disinfectants could cure people when injected into their bodies. (That also leads to death.)

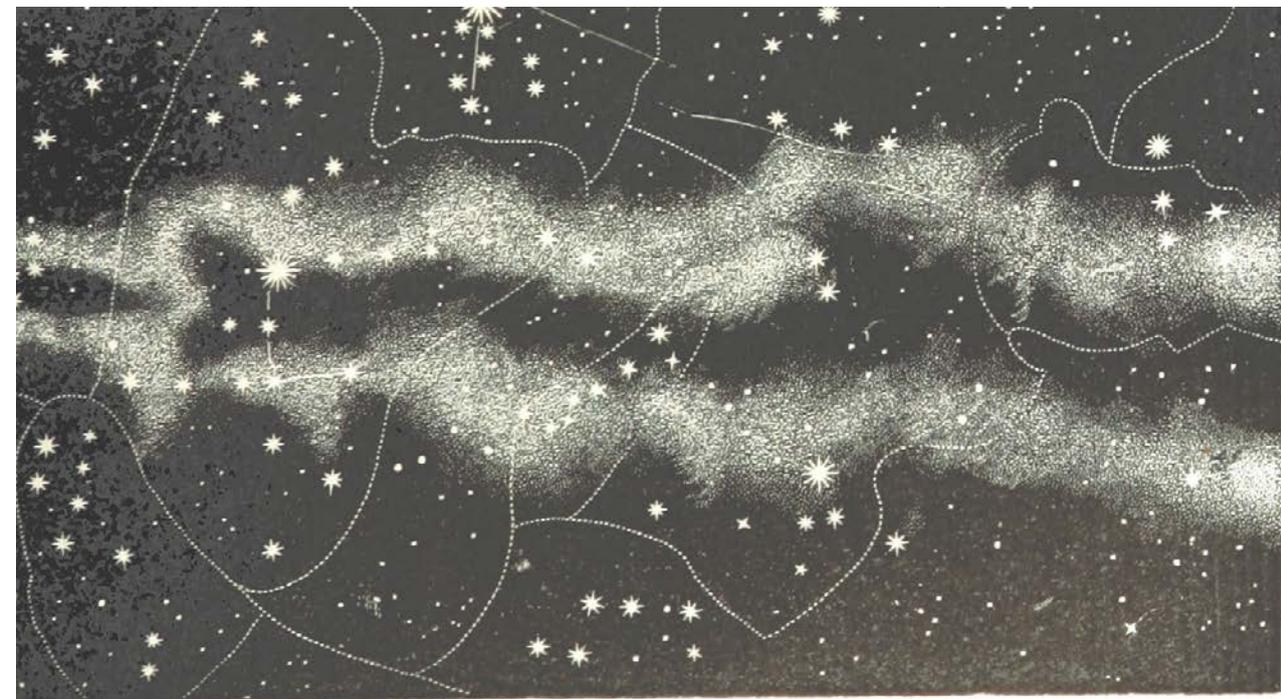
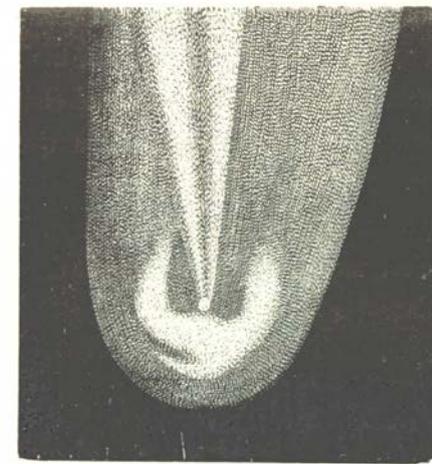
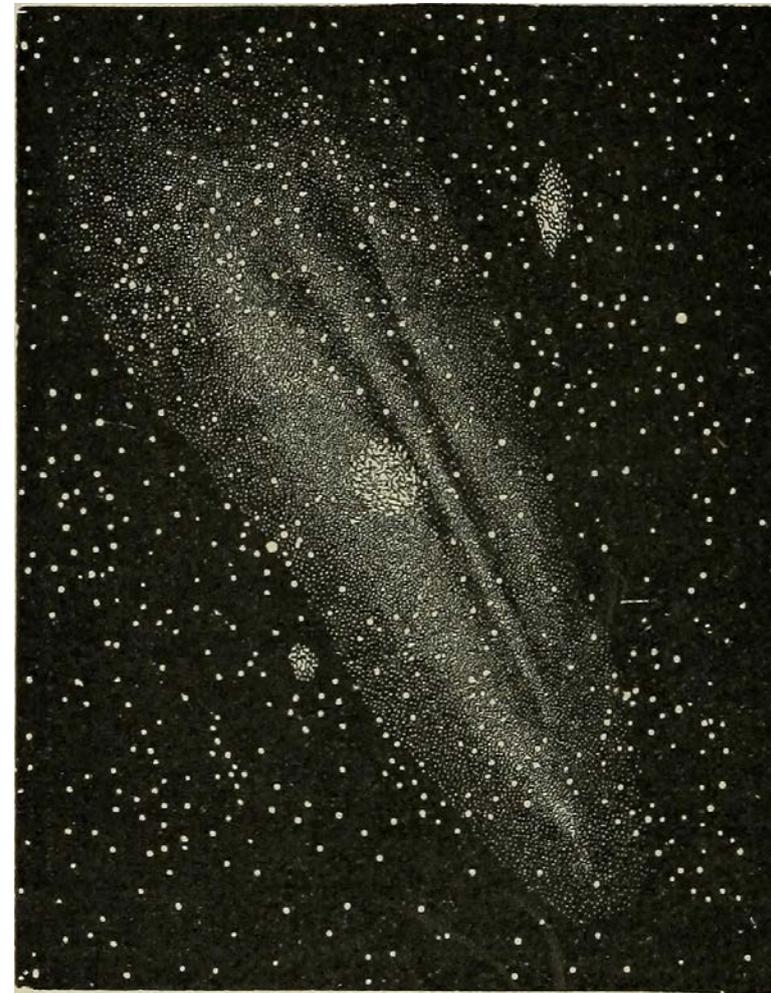
But people do take medical advice from politicians. An Arizona man afraid of COVID-19 died after consuming chloroquine phosphate, which he and his wife had sitting on the back of a shelf after using it to treat koi fish for parasites. The pandemic has exposed many weaknesses in the feedback loop of society, govern-

ment, the media, and science, including the difficulty of seeding accurate medical information with the masses. Many on the left and right decry a broken political and news media system, but Tyson believes the problem isn’t mega-influencers like Trump. Rather it’s the general public’s desire to take their advice on complex topics — like the science of virology — that such influencers know nothing about.

Tyson’s not upset with the public, who follow Trump’s advice. “As an educator, I can’t get angry with you,” he says. Or even Trump himself. “Trump was elected by 60 million people, right? So, you could say all you want about Trump, kick him out of office, whatever. [There’s] still the 60 million fellow Americans who walk among us who voted for him. So, what are you going to do with them?”

Tyson also isn’t upset with Facebook, Twitter, and other social platforms that serve as today’s biggest conduits for misinformation. After all, in the realm of modern media’s history, these networks are tadpoles. “As an educator and as a scientist, I’m leaning towards, let’s figure out a way to train people in school to not fall victim to false information, and how to judge what is likely to be false relative to what is likely to be true. And that’s hard, but you and I have never had a class in that, have we? We’ve had biology classes, we’ve had English lit, we’ve had classes on Shakespeare — we have classes on 100 things and none of them are on the ability to distinguish what is true and what is not.”

This is why Tyson himself doesn’t engage in Trump bashing on his social feeds, but does try to get people to differentiate factual science from fake news. “I feel responsibility to participate in the enlightenment of culture and of civilization, because I have that access,” says Tyson, who has 13.9M followers on Twitter, 1.2M on Instagram, and 4.2M on Facebook. He doesn’t tell his followers not to inject themselves with Clorox (“no one likes being told what to do”), but tries to get them to visualize a pandemic’s impact by comparing it to, say, a throng of rabbits. “Left unchecked, 1,000 rabbits in 5 years, become 7-billion, the human population of the World. After 15 years, a ‘land-ocean’ of rabbits fills to one-kilometer depth across all of Earth’s conti-





nents. Viruses can reproduce waaaay faster than Rabbits,” he tweeted on April 6, after much of the nation had locked down to slow the pandemic’s spread. For added viral impact, he attached a photo of an adorable, perhaps appropriately scared-looking, white bunny.

Tyson is a rare scientist-turned-celebrity. His appeal isn’t acting in movies or singing dance-pop anthems (if only). Rather, his life’s work is making science fun and interesting to as many people as possible through his best-selling books on astrophysics and his directorship of the planetarium at the American Museum of Natural History in New York. His longstanding place in popular culture is an exception, not the rule. And he believes his fellow celebrities, actors and pop music stars and internet influencers, should aid the public’s quest for accurate scientific information. And in order to do that, they must point their followers to experts and organizations who know what they’re talking about. “It could be to a website, it could be to a talk that was given. I would say that that’s where the responsibility lies if you control the interests of a million people,” he says.

One example of this is Lady Gaga’s March 14 Instagram of herself on her couch with her three dogs with the caption, “So I talked to some doctors and scientists. It’s not the easiest for everyone right now but the kindest/healthiest thing we can do is self-quarantine

and not hang out with people over 65 and in large groups. I wish I could see my parents and grandmas right now but it’s much safer to not so I don’t get them sick in case I have it. I’m hanging at home with my dogs.” (All the celebrities here in this article are my references, not Tyson’s, who does not call out specific people.)

Of course, not all celebrities message responsibly. Jessica Biel and Jenny McCarthy have faced scorn for public stances against vaccines. Gwyneth Paltrow and her media brand GOOP have faced backlash for promoting homeopathic treatments with no basis in science. “The New Age Movement is a cultural idea, it has nothing to do with religion, has nothing to do with politics, and it’s people who were rejecting objectively established science in part or in total because they have a belief system that they want to attach to it, okay? This is how you get the homeopathic remedies,” says Tyson. “That’s why science exists, so that we don’t have to base decisions on belief systems.” ■

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Amy Ode11 is a journalist who writes about fashion, media, pop culture, and women’s issues, and often wonders if she should have become a biologist instead.



4



Whistleblowers: The Science Sleuths Holding Fraudulent Research Accountable

Conversation facilitated by Kira Peikoff

Elisabeth Bik



Ivan Oransky



Introduction by Mary Inman, whistleblower attorney

For most people, when they see the word “whistleblower,” the image that leaps to mind is a lone individual bravely stepping forward to shine a light on misconduct she has witnessed first-hand. Meryl Streep as Karen Silkwood exposing safety violations observed while working the line at the Kerr-McGee plutonium plant. Matt Damon as Mark Whitacre in *The Informant!*, capturing on his pocket recorder clandestine meetings between his employer and its competitors to fix the price of lysine. However, a new breed of whistleblower is emerging who isn’t at the scene of the crime but instead figures it out after the fact through laborious review of publicly available information and expert analysis. Elisabeth Bik belongs to this new class of whistleblower.

Using her expertise as a microbiologist and her trained eye, Bik studies publicly available scientific papers to sniff out potential irregularities in the images that suggest research fraud, later seeking retraction of the offending paper from the journal’s publisher. There’s no smoking gun, no first-hand account of any kind. Just countless hours spent reviewing scores of scientific papers and Bik’s skills and dedication as a science fraud sleuth.

While Bik’s story may not as readily lend itself to the big screen, her work is nonetheless equally heroic. By tirelessly combing scientific papers to expose research fraud, Bik is playing a vital role in holding the scientific publishing process accountable and ensuring that misleading information does not spread unchecked. This is important work in any age, but particularly so in the time of COVID, where we can ill afford the setbacks and delays of scientists building on false science. In the present climate, where science is politicized and scientific principles are under attack, strong voices like Bik’s must rise above the din to ensure the scientific information we receive, and our governments act upon, is accurate. Our health and wellbeing depend on it.

Whistleblower outsiders like Bik are challenging the traditional concept of what it means to be a whistleblower. Fortunately for us, the whistleblower community is a broad church. As with most ecosystems, we all benefit from a diversity of voices —whistleblower insiders and outsiders alike. What follows is an illuminating conversation between Bik, and Ivan Oransky, the co-founder of Retraction Watch, an influential blog that reports on retractions of scientific papers and related topics.

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Mary Inman is a partner in the London office of Constantine Cannon, where she heads the firm’s international whistleblower practice and specializes in representing whistleblowers from the U.K., Europe and worldwide under the American whistleblower reward programs.



Ivan: I'd like to hear your thoughts, Elisabeth, on an *L.A. Times* story, which was picking up a preprint about mutations and the novel coronavirus, alleging that the virus is mutating to become more infectious – even though this conclusion wasn't actually warranted.



Elisabeth: A lot of the news around it is picking up on one particular side of the story that is maybe not that much exaggerated by the scientists. I don't think this paper really showed that the mutations were causing the virus to be more virulent. Some of these viruses continuously mutate and mutate and mutate, and that doesn't necessarily make a strain more virulent. I think in many cases, a lot of people want to read something in a paper that is not actually there.

Ivan: The tone level, everything that's being published now, it's problematic. It's being rushed, here it wasn't even peer-reviewed. But even when they are peer-reviewed, they're being peer-reviewed by people who often aren't really an expert in that particular area.

Elisabeth: That's right.

Ivan: To me, it's all problematic. At the same time, it's all really good that it's all getting out there. I think that five or 10 years ago, or if we weren't in a pandemic, maybe that paper wouldn't have appeared at all. It would have maybe been submitted to a top-ranked journal and not have been accepted, or maybe it would have been improved during peer review and bounced down the ladder a bit to a lower-level journal.

Yet, now, because it's about coronavirus, it's in a major newspaper and, in fact, it's getting critiqued immediately.

Maybe it's too Pollyanna-ish, but I actually think that quick uploading is a good thing. The fear people have about preprint servers is based on this idea that the peer-reviewed literature is perfect. Once it is in a peer-reviewed journal, they think it must have gone through this incredible process. You're laughing because-

Elisabeth: I am laughing.

Ivan: You know it's not true.

Elisabeth: Yes, we both know that. I agree and I think in this particular situation, a pandemic that is unlike something our generation has seen before, there is a great, great need for fast dissemination of science.

If you have new findings, it is great that there is a thing called a preprint server where scientists can quickly share their results, with, of course, the caveat that it's not peer-reviewed yet.

It's unlike the traditional way of publishing papers, which can take months or years. Preprint publishing is a very fast way of spreading your results in a good way so that is what the world needs right now.

On the other hand, of course, there's the caveat that these are brand new results and a good scientist usually thinks about their results to really interpret it well. You have to look at it from all sides and I think with the rushed publication of preprint papers, there is no such thing as carefully thinking about what results might mean.

So there's this delicate balance where on one hand we want to spread results really fast as scientists, but on the other hand, we know it's incomplete, it's rushed and it's not great. This might be hard for the general audience to understand.



Ivan: I still think the benefits of that dissemination are more positive than negative.

Elisabeth: Right. But there's also so many papers that come out now on preprint servers and most of them are not that great, but there are some really good studies in there. It's hard to find those nuggets of really great papers. There's just a lot of papers that come out now.

Ivan: Well, you've made more than a habit of finding problems in papers. These are mostly, of course, until now published papers that you examined, but what is this time like for you? How is it different?



Elisabeth: It's different because in the beginning I looked at several COVID-19-related papers that came out and wrote some critiques about it. I did experience a lot of backlash because of that. So I felt I had to take a break from social media and from writing about COVID-19.

I focused a little bit more on other work because I just felt that a lot of these papers on COVID-19 became so politically divisive that if you tried to be a scientist and think critically about a paper, you were actually assigned to a particular political party or to be against other political parties. It's hard for me to be sucked into the political discussion and to the way that our society now is so completely divided into two camps that seem to be not listening to each other.

Ivan: I was curious about that because I've followed your work for a number of years, as you know, and certainly you have had critics before. I'm thinking of the case in China that you uncovered, the leading figure in the Chinese Academy who was really a powerful political figure in addition to being a scientist.

Elisabeth: So that was a case in which I found a couple of papers at first from a particular group in China, and I was just posting on a website called PubPeer, where you can post comments, concerns about papers. And in this case, these were image duplication issues, which is my specialty.

I did not realize that the group I was looking at at that moment was led by one of the highest ranked scientists in China. If I had known that, I would probably not have posted that under my full name, but under a pseudonym. Since I had already posted, some people were starting to send me direct messages on Twitter like, "OMG, the guy you're posting about now is the top scientist in China so you're going to have a lot of backlash."

Then I decided I'll just continue doing this. I found a total of around 50 papers from this group and posted all of them on PubPeer. That story quickly became a very popular story in China: number two on Sina Weibo, a social media site in China.

I was surprised it wasn't suppressed by the Chinese government, it was actually allowed by journalists that were writing about it, and I didn't experience a lot of backlash because of that.

Actually the Chinese doctor wrote me an email saying that he appreciated my feedback and that he would look into these cases. He sent a very polite email so I sent him back that I appreciated that he would look into these cases and left it there.

Ivan: There are certain subjects that I know when we write about them in Retraction Watch, they have tended in the past to really draw a lot of ire. I'm thinking anything about vaccines and autism, anything about climate change, stem cell research.

For a while that last subject has sort of died down. But now it's become a highly politically charged atmosphere. Do you feel that this pandemic has raised the profile of people such as yourself who we refer to as scientific sleuths, people who look critically and analytically at new research?

Elisabeth: Yeah, some people. But I'm also worried that some people who are great scientists and have shown a lot of critical thinking are being attacked because of that. If you just look at what happened to Dr. Fauci, I think that's a prime example. Where somebody who actually is very knowledgeable and very cautious of new science has not been widely accepted as a great leader, in our country at least. It's sad to see that. I'm just worried how long he will be at his position, to be honest.



Ivan: We noticed a big uptick in our traffic in the last few days to Retraction Watch and it turns out it was because someone we wrote about a number of years ago has really hopped on the bandwagon to try and discredit and even try to have Dr. Fauci fired.

It's one of these reminders that the way people think about scientists has, in many cases, far more to do with their own history or their own perspective going in than with any reality or anything about the science. It's pretty disturbing, but it's not a new thing. This has been happening for a while.



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You can go back and read sociologists of science from 50-60 years ago and see the same thing, but I just don't think that it's in the same way that it is now, maybe in part because of social media.

Elisabeth: I've been personally very critical about several studies, but this is the first time I've experienced being attacked by trolls and having some nasty websites written about me. It is very disturbing to read.



Ivan: It is. Yet you have been a fearless and vocal critic of some very high-profile papers, like the infamous French study about hydroxychloroquine.



Elisabeth: Right, the paper that came out was immediately tweeted by the President of the United States. At first I thought it was great that our President tweeted about science! I thought that was a major breakthrough. I took a look at this paper. It had just come out that day, I believe. The first thing I noticed is that it was accepted within 24 hours of being submitted to the journal. It was actually published in a journal where one of the authors is the editor-in-chief, which is a huge conflict of interest, but it happens.

But in this particular case, there were also a lot of flaws with the study and that, I think, should have been caught during peer review. The paper was first published on a preprint server and then within 24 hours or so it was published in that paper, supposedly after peer review.

There were very few changes between the preprint version and the peer review paper. There were just a couple of extra lines, extra sentences added here and there, but it wasn't really, I think, critically looked at. Because there were a lot of things that I thought were flaws.

Just to go over a couple of them. This paper showed supposedly that people who were treated with hydroxychloroquine and azithromycin were doing much better by clearing their virus much faster than people who were not treated with these drugs.

But if you look carefully at the paper there were a couple of people who were left out of the study. So they were treated with hydroxychloroquine, but they were not shown in the end results of the paper. All six people who were treated with the drug combination were clearing the virus within six days, but there were a couple of others who were left out of the study. They also started the drug combination, but they stopped taking the drugs for several reasons and three of them were admitted to the intensive care, one died, one had some side effects and one apparently walked out of the hospital.

They were left out of the study but they were actually not doing very well with the drug combination. It's not very good science if you leave out people who don't do very well with your drug combination in your study. That was one of my biggest critiques of the paper.

Ivan: What struck us about that case was, in addition to what you, of course, mentioned, the fact that Trump tweeted it and was talking about hydroxychloroquine, was that it seemed to be a perfect example of, "well, it was in a peer review journal." Yeah, it was a preprint first, but, well, it's a peer review journal. And yet, as you point out, when you look at the history of the paper, it was accepted in 24 hours.

If you talk to most scientists, the actual act of a peer review, once you sit down to do it and can concentrate, a good one takes, again, these are averages, but four hours, a half a day is not unreasonable. So you had to find three people who could suddenly review this paper. As you pointed out, it was in a journal where one of the authors was editor.

Then some strange things also happened, right? The society that actually publishes the journal, they came out with a statement saying *this wasn't up to our standards*, which is odd. Then Elsevier came in, they're the ones who are actually contracted to publish the journal for the society. They said, basically, "Oh, we're going to look into this now too."

It just makes you wonder what happened before the paper was actually published. All the people who were supposed to have been involved in doing the peer review or checking on it are clearly very distraught about what actually happened. It's that scene from *Casablanca*, "I'm shocked, shocked there's gambling going on here." And then, "Your winnings, sir."



Elisabeth: Yes.

Ivan: And I don't actually blame the public, I don't blame reporters for getting a bit confused about what it all means and what they should trust. I don't think trust is a binary any more than anything else is a binary. I don't think that something that's been peer-reviewed is perfect and something that hasn't been peer reviewed, you should never bother reading it. I think everything is much more gray.

Yet we've turned things into a binary. Even if you go back before coronavirus, coffee is good for you, coffee is bad for you, red wine, chocolate, all the rest of it. A lot of that is because of this sort of binary construct of the world for journalists, frankly, for scientists that need to get their next grants. And certainly for the general public, they want answers.

On the one hand, if I had to choose what group of experts, or what field of human endeavor would I trust with finding the answer to a pandemic like this, or to any crisis, it would absolutely be scientists. Hands down. This is coming from someone who writes about scientific fraud.

But on the other hand, that means that if scientists aren't clear about what they don't know and about the nuances and about what the scientific method actually allows us to do and learn, that just sets them up for failure. It sets people like Dr. Fauci up for failure.

Elisabeth: Right.

Ivan: It sets up any public health official who has a discussion about models. There's a famous saying: "All models are wrong, but some are useful."

Just because the projections change, it's not proof of wrongness, it's not proof that the model is fatally flawed. In fact, I'd be really concerned if the projections didn't change based on new information. I would love it if this whole episode did lead to a better understanding of the scientific process and how scientific publishing fits into that — and doesn't fit into it.

Elisabeth: Yes, I'm with you. I'm very worried that the general audience's perspective is based on maybe watching too many movies where the scientist comes up with a conclusion one hour into the movie when everything is about to fail. Like that scene in Contagion where somebody injects, I think, eight monkeys, and one of the monkeys survives and boom we have the vaccine. That's not really how science works. Everything takes many, many years and many, many applications where usually your first ideas and your first hypothesis turn out to be completely wrong.

Then you go back to the drawing board, you develop another hypothesis and this is a very reiterative process that usually takes years. Most of the people who watch the movie might have a very wrong idea and wrong expectations about how science works. We're living in the movie Contagion and by September, we'll all be vaccinated and we can go on and live our lives. But that's not what is going to happen. It's going to take much, much longer and we're going to have to change the models every time and change our expectations. Just because we don't know all the numbers and all the facts yet.

Ivan: Generally it takes a fairly long time to change medical practice. A lot of times people see that as a bad thing. What I think that ignores, or at least doesn't take into as much account as I would, is that you don't want doctors and other health care professionals to turn on a dime and suddenly switch. Unless, of course, it turns out there was no evidence for what you were looking at.

It's a complicated situation.
Everybody wants scientists to be engineers, right?



Elisabeth: Right.

Ivan: I'm not saying engineering isn't scientific, nor am I saying that science is just completely whimsical, but there's a different process. It's a different way of looking at things and you can't just throw all the data into a big supercomputer, which is what I think a lot of people seem to want us to do, and then the obvious answer will come out on the other side.

Elisabeth: No. It's true and a lot of engineers suddenly feel their inherent need to solve this as a problem. They're not scientists and it's not building a bridge over a big river. But we're dealing with something that is very hard to solve because we don't understand the problem yet. I think scientists are usually first analyzing the problem and trying to understand what the problem actually is before you can even think about a solution.

Ivan: I think we're still at the understanding the problem phase.

Elisabeth: Exactly. And going back to the French group paper, that promised such a result and that was interpreted as such by a lot of people including presidents, but it's a very rare thing to find a medication that will have a 100% curation rate. That's something that I wish the people would understand better. We all want that to happen, but it's very unlikely and very unprecedented in the best of times.

Ivan: I would second that and also say that the world needs to better value the work that people like Elisabeth and others are doing. Because we're not going to get to a better answer if we're not rigorous about scrutinizing the literature and scrutinizing the methodology and scrutinizing the results.

It's a relatively new phenomenon that you're able to do this at any scale at all, and even now it's at a very small scale. Elisabeth mentioned PubPeer and I'm a big fan — also full disclosure, I'm on their board of directors as a volunteer — it's a very powerful engine for readers and journal editors and other scientists to discuss issues.

And Elisabeth has used it really, really well. I think we need to start giving credit to people like that. And, also creating incentives for that kind of work in a way that science hasn't yet.



Elisabeth: Yeah. I quit my job to be able to do this work. It's really hard to combine it with a job either in academia or industry because we're looking for or criticizing papers and it's hard when you are still employed to do that.

I try to make it about the papers and do it in a polite way, but still it's a very hard job to do if you have a daytime job and a position and a career to worry about. Because if you're critical of other academics, that could actually mean the end of your career and that's sad. They should be more open to polite criticism.



Ivan: And for the general public, if you're reading a newspaper story or something online about a single study and it doesn't mention any other studies that have said the same thing or similar, or frankly, if it doesn't say anything about any studies that contradicted it, that's probably also telling you something.

Say you're looking at a huge painting of a shoreline, a beach, and a forest. Any single study is just a one-centimeter-by-one-centimeter square of any part of that canvas. If you just look at that, you would either think it was a painting of the sea, of a beach, or of the forest. It's actually all three of those things.

We just need to be patient, and that's very challenging to us as human beings, but we need to take the time to look at the whole picture. ■

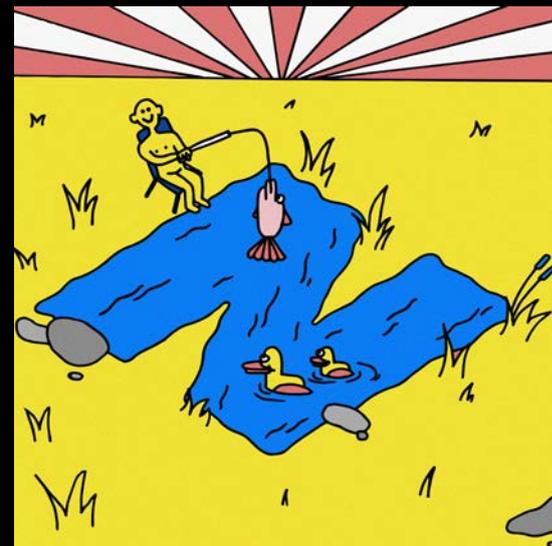
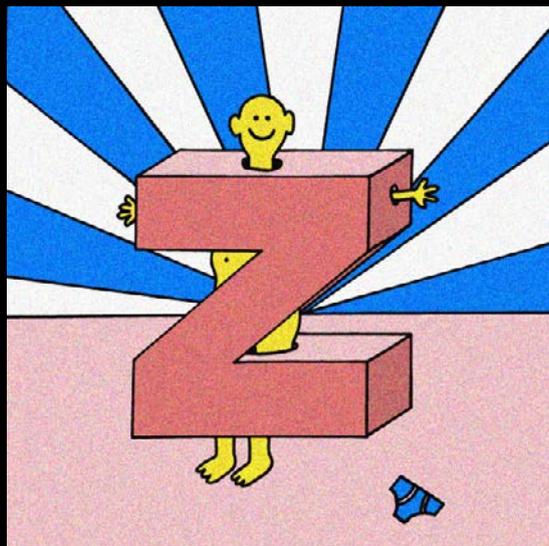
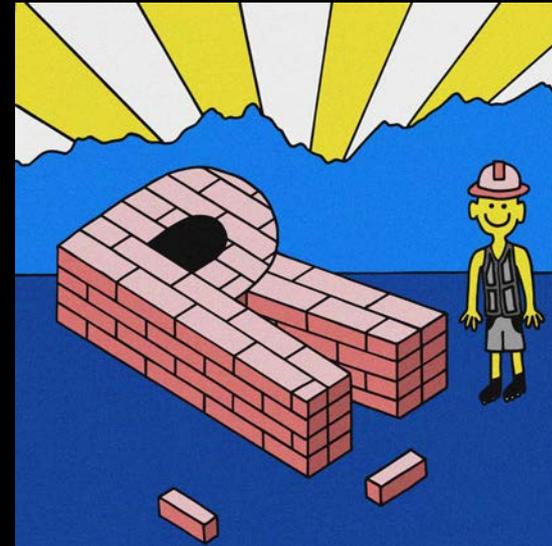
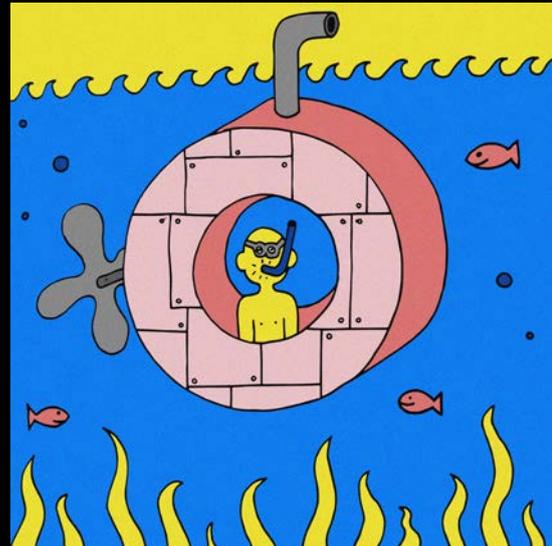
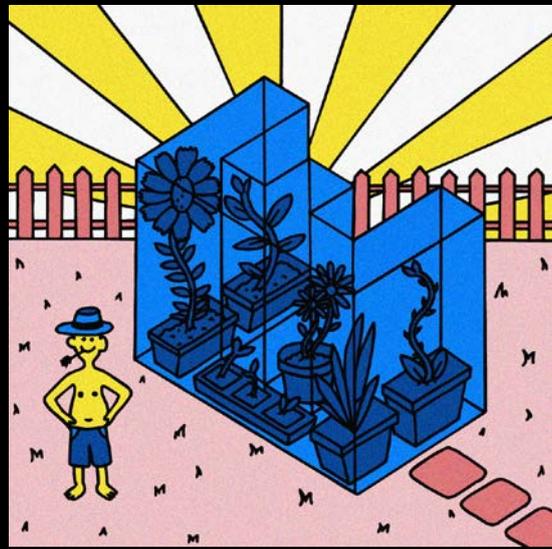
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DISCLAIMER:

Neither Elisabeth Bik nor Ivan Oransky was compensated for participation in *The Pandemic Issue*. While the magazine's editors suggested broad topics for discussion, consistent with Bik's and Oransky's work, neither they nor the magazine's underwriters had any influence on their conversation.



PARADIGM SHIFT



5



The illustrations in this piece are sourced from the U.N.'s Creative Content Hub, a collection of free artwork generously donated by creators "to educate, uplift, and inspire people all across the world through the global COVID pandemic crisis."

Companies:

The Biggest Challenge for a COVID-19 Vaccine

Making It Accessible and Affordable

By Kenneth Miller



Although no one has conducted a survey on the topic, it's safe to say that a single hope unites much of humanity at the present moment: the prospect of a vaccine for COVID-19, which has infected some 6 million people, killed at least 350,000, and sent the global economy into a tailspin since it first appeared in China last December.

Scientists are racing to make that vision a reality. As of this writing, eight vaccine candidates are in clinical trials and over 100 others are in preclinical development, in a dozen countries. Pointing to new technology and compressed testing protocols, experts predict a winner could emerge in 12 to 18 months—a fraction of the four years it took to develop the previous record-holder, the mumps vaccine, in the 1960s. Teams at Oxford University and Boston-based Moderna Therapeutics say they could have a product ready even sooner, if the formulas they're testing prove safe and effective. A just-announced White House initiative, Operation Warp Speed, aims to fast-track multiple candidates, with the goal of delivering 100 million doses in November and another 200 million by January 2021.

These timetables could prove wildly over-optimistic. But even if the best-case scenario comes true, and a viable COVID-19 vaccine emerges this fall, a gargantuan challenge remains: getting the shot to everyone who needs it. Epidemiologists figure that at least 70 percent of Earth's population—or 5.6 billion people—would have to be inoculated to achieve “herd immunity,” in which each person who catches the disease passes it to less than one other individual. “In order to stop the pandemic, we need to make the vaccine available to almost every person on the planet,” Microsoft co-founder Bill Gates blogged in April, as his foundation pledged \$300 million to the effort. “We've never delivered something to every corner of the world before.”

The difficulties are partly logistical, partly political, and largely a combination of the two. Overcoming those obstacles will require unprecedented cooperation among national governments, international organizations, and profit-minded corporations—in an era when nationalist rivalries are rampant and global leadership is up for grabs.

That may be tougher than developing the vaccine itself.

Logistical Conundrums

Manufacturing and distributing billions of vaccine doses would be a daunting task even in the most harmonious of times. Take the packaging problem. The vaccines under development range from old-school (based on inactivated or weakened viruses) to cutting-edge (using snippets of RNA or DNA to train the immune system to attack the invader). Some may work better than others for different patient groups—the young versus the elderly, for example. All, however, must be stored in vials and administered with syringes.

Among the handful of U.S. companies that manufacture such products, many must import the special glass tubing for vials, as well as the polypropylene for syringe barrels and the rubber or silicone for stoppers and plungers. These materials are commonly sourced from China and India, where lockdowns and export bans restrict supply. Rick Bright, the ousted director of the federal Biomedical Advanced Research and Development Authority (BARDA), claims he was ignored when he warned the Trump Administration that a medical-glass shortage was looming before the coronavirus crisis hit; securing enough to vaccinate 300 million Americans, he told Congress in May, could take up to two years.

Getting the vaccine to poorer countries presents further hurdles. To begin with, there's refrigeration. Inactivated or live vaccines must be kept between 2 and 8 degrees Centigrade (or 35 to 46 degrees Fahrenheit); RNA or DNA vaccines require much colder temperatures—as low as -80 degrees. This makes storage and transport challenging in parts of the world that lack reliable electricity.

Tracking vaccine distribution is another conundrum for low- to middle-income countries. “Supply chain management is really about information,” explains Rebecca Weintraub, assistant professor of global health and social medicine at Harvard Medical School and director of the Better Evidence project at Harvard's Ariadne Labs. “It's about leveraging data to determine

demand, predict behavior, and understand the flow of the product itself.” Systems for collecting and analyzing such data can be hard to find in poorer regions, she notes. What's more, many people in those areas lack any type of ID card, making it difficult to know who has or hasn't received a vaccine.

Weintraub and two coauthors published an article in April in the *Harvard Business Review*, suggesting solutions to these and other developing-world problems: solar direct-drive refrigerators, app-based data-capture systems, biometric digital IDs. But such measures—not to mention purchasing adequate supplies of vaccine—would require massive funding.

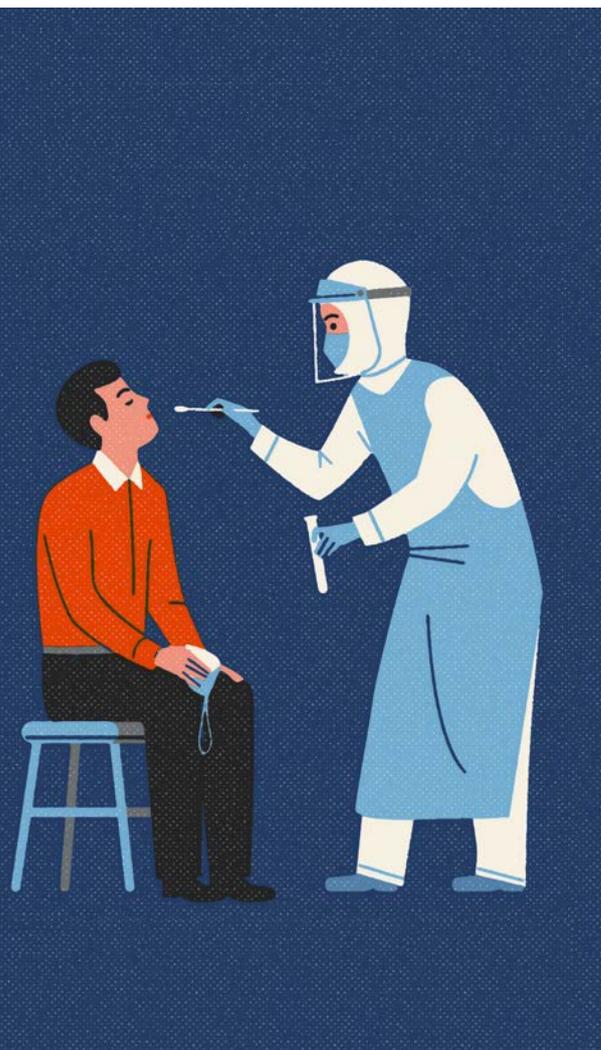
And that's where the logistical begins to overlap with the political.

Global Access Versus “Vaccine Nationalism”

A patchwork of institutions have already begun laying the groundwork for achieving worldwide, equitable access to COVID-19 vaccines. In February, the World Bank and the Norway-based Coalition for Epidemic Preparedness Innovations (CEPI) cohosted a global consultation on funding vaccine development and manufacturing. In late April, the World Health Organization (WHO), in collaboration with dozens of governments, nonprofits, and industry leaders, launched a program called the Access to COVID-19 Tools Accelerator to expedite such efforts.

Soon afterward, the European Union, along with six countries and the Bill and Melinda Gates Foundation, held a Coronavirus Global Response telethon that raised \$8 billion to support Gavi, the Vaccine Alliance—a public-private partnership that subsidizes immunization in low-income countries. The United States and Russia, however, chose not to participate.

This snub by the world's remaining superpower and one of its principal challengers worried many





observers. “I am concerned about what I call vaccine nationalism,” CEPI executive director Richard Hatchett told the Los Angeles Times. “That’s the tension between obligations elected leaders will feel to protect the lives of their citizens” versus the imperative for global sharing.

Some signs point to a possible rerun of the hoarding that accompanied the 2009 H1N1 influenza pandemic, when wealthy nations bought up virtually all vaccine supplies—denying them to poorer countries, and sometimes to one another. Operation Warp Speed has declared an “America First” policy for any vaccine arising from its efforts. Pharma giant Sanofi recently suggested that it would take a similar approach, since the U.S. was first to fund the company’s COVID-19 research. (Sanofi’s CEO backtracked after officials in France, where the firm is headquartered, protested.) The Oxford group, which is partnering with British-based drug maker AstraZeneca, intends to prioritize Great Britain.

Yet momentum is building for more generous strategies as well. In May, over 100 current and former world leaders, along with prominent economists and public health experts, issued an open letter calling for a “people’s vaccine” for COVID-19, which would be patent-free, distributed globally, and available to all countries free of charge. At the WHO’s annual World Health Assembly, all 194 member states accepted a resolution urging that vaccines for the disease be made available as a “global public good”—though the U.S. dissociated itself from a clause proposing a patent pool to keep costs down, which it argued might disincentivize “innovators who will be essential to the solutions the whole world needs.”

Gavi, for its part, plans to launch a mechanism designed to encourage those innovators while promoting accessibility: an advance market commitment, in which countries pledge to purchase a vaccine, with no money down. Future contributions will be based on the value of the product to their health systems and their ability to pay.

A few private-sector players are stepping up, too. U.S.-based Johnson & Johnson, which has received nearly

half a billion dollars from the federal government for COVID-19 vaccine research, has promised to provide up to 900 million doses on a not-for-profit basis, if its trials pan out. Other companies have agreed to produce vaccines on a “cost-plus” basis, with a smaller-than-usual profit margin.

How Sharing Can Pay Off

No one knows how all this will work out if and when a vaccine becomes available. (Another wild card: Washington has threatened to cut funding to the WHO over its alleged favoritism toward China, which could hobble the agency’s ability to coordinate distribution.) To public health experts, however, it’s clear that ensuring accessibility is not just a matter of altruism.

“A historic example is smallpox,” Rebecca Weintraub observes. “When it kept getting reintroduced into high-income countries from low-income countries, the rich countries realized it was worth investing in the vaccine for countries that couldn’t afford it.” After a two-decade campaign led by the WHO, the last case of this ancient scourge was diagnosed in 1977.

Conversely, vaccine nationalism doesn’t just hurt poor countries. During the H1N1 pandemic, which killed an estimated 284,000 people worldwide, production problems led to shortages in the United States. But Australia stopped a domestic manufacturer from exporting doses to the U.S until all Aussies had been immunized.

Such considerations, Weintraub believes, might help convince even the most reluctant rich-country leaders that an accessible vaccine—if deployed in an epidemiologically targeted way—would serve both the greater good and the national interest. “I suspect the pressures put on our politicians to act globally will be significant,” she says.

Other analysts share her guarded optimism. Kelly Moore, who teaches health policy at Vanderbilt University Medical Center, oversaw Tennessee’s immunization programs for more than a decade, and later became a member of the Sabin-Aspen Vaccine Science & Policy Group—a panel of international experts that in 2019 released a report titled “Accelerating the Development of a Universal Influenza Vaccine.” (The group is affiliated with the Aspen Institute, a co-publisher of this magazine.) The 117-page document provided a road map toward a long-sought goal: creating a flu shot that doesn’t need to be reformulated each year to target changing viral strains.

“One lesson we learned was that it’s crucial to deploy financial resources in a systematic way to support coordination among laboratories that would typically be competitors,” Moore says. And that, she adds, is happening with COVID-19, despite nationalist frictions: scientists from Sanofi joining forces with those at rival GSK; researchers at other companies allying with teams at government laboratories; university labs worldwide sharing data across borders. “I have been greatly encouraged to see the amount of global collaboration involved in this enterprise. Partners are working together who would normally never be partners.”

For Moore, whose 77-year-old mother survived a bout with the disease, the current pandemic has hit close to home. “It’s essential to realize that a threat anywhere is a threat everywhere,” she says. “Morally and ethically, we have a tremendous obligation to ensure that the most vulnerable have access to an affordable vaccine, irrespective of where they live.” ■

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Media:

Isaac Asimov on the History of Infectious Disease—and How Humanity Learned to Fight Back

By Isaac Asimov

Forward:

Humanity has always faced existential threats from dangerous microbes, and though this is the first pandemic in our lifetimes, it won't be the last our species will ever face. This newly relevant work by beloved sci-fi writer Isaac Asimov, an excerpt from his 1979 book, *A Choice of Catastrophes*, establishes that reality in its historical context and makes clear how far we have come since ancient times. But by some measures, we are still in the earliest stages of figuring out how to effectively neutralize such threats. Advancing progress as fast as we can—by leveraging all the insights of modern science—offers our best hope for containing this pandemic and those that will inevitably follow.

—Kira Peikoff, Editor

Infectious Disease

An even greater danger to humanity than the effect of small, fecund pests on human beings, their food, and their possessions, is their tendency to spread some forms of infectious disease.

Every living organism is subject to disease of various sorts, where disease is defined in its broadest sense as “dis-ease,” that is, as any malfunction or alteration of the physiology or biochemistry that interferes with the smooth workings of the organism. In the end, the cumulative effect of malfunctions, misfunctions, nonfunctions, even though much of it is corrected or patched up, produces irreversible damage—we call it old age—and, even with the best care in the world, brings on inevitable death.

There are some individual trees that may live five thousand years, some cold-blooded animals that may live two hundred years, some warm-blooded animals that may live one hundred years, but for each multicellular individual death comes as the end.

This is an essential part of the successful functioning of life. New individuals constantly come into being with new combinations of chromosomes and genes, and with mutated genes, too. These represent new attempts, so to speak, at fitting the organism to the environment. Without the continuing arrival of new organisms that are not mere copies of the old, evolution would come to a halt. Naturally, the new organisms cannot perform their role properly unless the old ones are removed from the scene after they have performed their function of producing the new. In short, the death of the individual is essential to the life of the species.

It is essential, however, that the individual not die before the new generation has been produced; at least, not in so many cases as to ensure the population dwindling to extinction.

The human species cannot have the relative immunity to harm from individual death possessed by the small and fecund species. Human beings are comparatively large, long-lived, and slow to reproduce, so that too rapid individual death holds within it the specter of catastrophe. The rapid death of unusually high numbers of human beings through disease can seriously dent the human population. Carried to an extreme, it is not too hard to imagine it wiping out the human species.

Most dangerous in this respect is that class of malfunction referred to as “infectious disease.” There are many disorders that affect a particular human being for one reason or another and may kill him or her, too, but which will not, in itself, offer a danger to the species, because it is strictly confined to the suffering individual. Where, however, a disease can, in some way travel from one human being to another, and where its occurrence in a single individual may lead to the death of not that one alone but of millions of others as well, then there is the possibility of catastrophe.

And indeed, infectious disease has come closer to destroying the human species in historic times than have the depredations of any animals. Although infectious disease, even at its worst, has never yet actually put an end to human beings as a living species (obviously), it can seriously damage a civilization and change the course of history. It has, in fact, done so not once, but many times.

What’s more, the situation has perhaps grown worse with the coming of civilization. Civilization has meant the development and growth of cities and the crowding of people into close quarters. Just as fire can spread much more rapidly from tree to tree in a dense forest than in isolated stands, so can infectious disease spread more quickly in crowded quarters than in sparse settlements.

To mention a few notorious cases in history:

In 431 B.C., Athens and its allies went to war with Sparta and its allies. It was a twenty-seven-year war that ruined Athens and, to a considerable extent, all of Greece. Since Sparta controlled the land, the entire Athenian population crowded into the walled city of Athens. There they were safe and could be provisioned by sea, which was controlled by the Athenian navy. Athens would very likely have won a war of attrition before long and Greece might have avoided ruin, but for disease.

In 430 B.C., an infectious plague struck the crowded Athenian population and killed 20 percent of them, including the charismatic leader, Pericles. Athens kept on fighting but it never recovered its population or its strength and in the end it lost.

Plagues very frequently started in eastern and southern Asia, where population was densest, and spread westward. In A.D. 166, when the Roman Empire was at its peak of strength and civilization under the hard-working philosopher-emperor Marcus Aurelius, the Roman armies, fighting on the eastern borders in Asia Minor, began to suffer from an epidemic disease (possibly smallpox). They brought it back with them to other provinces and to Rome itself. At its height, 2,000 people were dying in the city of Rome each day. The population began to decline and did not reach its preplague figure again until the twentieth century. There are a great many reasons advanced for the long, slow decline of Rome that followed the reign of Marcus Aurelius, but the weakening effect of the plague of 166 surely played a part.

Even after the western provinces of the empire were torn away by invasions of the German tribes, and Rome itself was lost, the eastern half of the Roman Empire continued to exist, with its capital at Constantinople. Under the capable emperor Justinian I, who came to the throne in 527, Africa, Italy, and parts of Spain were taken and, for a while, it looked as though the empire might be reunited. In 541, however, the bubonic plague struck. It was a disease that attacked rats primarily, but one that fleas could spread to human beings by biting first a sick rat and then a healthy human being. Bubonic disease was fast-acting and often quickly fatal. It may even have been accompanied by a more deadly variant, pneumonic plague, which can leap directly from one person to another.

For two years the plague raged, and between one-third and one-half of the population of the city of Constantinople died, together with many people in the countryside outside the city. There was no hope of uniting the empire thereafter and the eastern portion, which came to be known as the Byzantine Empire, continued to decline thereafter (with occasional rallies).

The very worst epidemic in the history of the human species came in the fourteenth century. Sometime in the 1330s, a new variety of bubonic plague, a particularly deadly one, appeared in central Asia. People began to die and the plague spread outward, inexorably, from its original focus.

Eventually, it reached the Black Sea. There on the Crimean peninsula, jutting into the north-central coast of that sea, was a seaport called Kaffa where the Italian city of Genoa had established a trading post. In October, 1347, a Genoese ship just managed to make it back to Genoa from Kaffa. The few men on board who were not dead of the plague were dying. They were carried ashore and thus the plague entered Europe and began to spread rapidly.

Sometimes one caught a mild version of the disease, but often it struck violently. In the latter case, the patient was almost always dead within one to three days after the onset of the first symptoms. Because the extreme dangers were marked by hemorrhagic spots that turned dark, the disease was called the “Black Death.”

The Black Death spread unchecked. It is estimated to have killed some 25 million people in Europe before it died down and many more than that in Africa and Asia. It may have killed a third of all the human population of the planet, perhaps 60 million people altogether or even more. Never before or after do we know of anything that killed so large a percentage of the population as did the Black Death.

It is no wonder that it inspired abject terror among the populace. Everyone walked in fear. A sudden attack of shivering or giddiness, a mere headache, might mean that death had marked one for its own and that no more than a couple of dozen hours were left in which to die. Whole towns were depopulated, with the first to die lying unburied while the survivors fled to spread the disease. Farms lay untended; domestic animals wandered uncared for. Whole nations—Aragon, for instance, in what is now eastern Spain—were afflicted so badly that they never truly recovered.

Distilled liquors had been first developed in Italy about 1100. Now, two centuries later they grew popular. The theory was that strong drink acted as a preventive against contagion. It didn't, but it made the drinker less concerned which, under the circumstances, was something. Drunkenness set in over Europe and it stayed even after the plague was gone; indeed, it has never left. The plague also upset the feudal economy by cutting down on the labor supply very drastically. This did as much to destroy feudalism as did the invention of gunpowder. (Perhaps the most distressing sidelight of the Black Death is the horrible insight into human nature that it offers. England and France were in the early decades of the Hundred Years War at the time. Although the Black Death afflicted both nations

and nearly destroyed each, the war continued right on. There was no thought of peace in this greatest of all crises faced by the human species.)

There have been other great plagues since, though none to match the Black Death in unrivaled terror and destruction. In 1664 and 1665, the bubonic plague struck London and killed 75,000.

Cholera, which always simmered just below the surface in India (where it is “endemic”) would occasionally explode and spread outward into an “epidemic.” Europe was visited by deadly cholera epidemics in 1831 and again in 1848 and 1853. Yellow fever, a tropical disease, would be spread by sailors to more northern seaports, and periodically American cities would be decimated by it. Even as late as 1905, there was a bad yellow fever epidemic in New Orleans.

The most serious epidemic since the Black Death, was one of “Spanish influenza” which struck the world in 1918 and in one year killed 30 million people the world over, and about 600,000 of them in the United States. In comparison, four years of World War I, just preceding 1918, had killed 8 million. However, the influenza epidemic killed less than 2 percent of the world's population, so that the Black Death remains unrivaled.

[...] Infectious disease is clearly more dangerous to human existence than any animal possibly could be, and we might be right to wonder whether it might not produce a final catastrophe before the glaciers ever have a chance to invade again and certainly before the sun begins to inch its way toward red gianthood.

What stands between such a catastrophe and us is the new knowledge we have gained in the last century and a half concerning the causes of infectious disease and methods for fighting it.

Microorganisms

People, throughout most of history, had no defense whatever against infectious disease. Indeed, the very fact of infection was not recognized in ancient and medieval times. When people began dying in droves, the usual theory was that an angry god was taking vengeance for some reason or other. Apollo's arrows were flying, so that one death was not responsible for another; Apollo was responsible for all, equally.



The Bible tells of a number of epidemics and in each case it is the anger of God kindled against sinners, as in 2 Samuel 24. In New Testament times, the theory of demonic possession as an explanation of disease was popular, and both Jesus and others cast our devils. The biblical authority for this has caused the theory to persist to this day, as witness by the popularity of such movies as *The Exorcist*.

As long as disease was blamed on divine or demonic influences, something as mundane as contagion was overlooked. Fortunately, the Bible also contains instructions for isolating those with leprosy (a name given not only to leprosy itself, but to other, less serious skin conditions). The biblical practice of isolation was for religious rather than hygienic reasons, for leprosy has a very low infectivity. On biblical authority, lepers were isolated in the Middle Ages, while those with really infectious disease were not. The practice of isolation, however, caused some physicians to think of it in connection with disease generally. In particular, the ultimate terror of the Black Death helped spread the notion of quarantine, a name which referred originally to isolation for forty (quarante in French) days.

The fact that isolation did slow the spread of a disease made it look as though contagion was a factor. The first to deal with this possibility in detail was an Italian physician, Girolamo Fracastoro (1478–1553). In 1546, he suggested that disease could be spread by direct contact of a well person with an ill one or by indirect contact of a well person with infected articles or even through transmission over a distance. He suggested that minute bodies, too small to be seen, passed from an ill person to a well one and that the minute bodies had the power of self-multiplication.

It was a remarkable bit of insight, but Fracastoro had no firm evidence to support his theory. If one is going to accept minute unseen bodies leaping from one body to another and do it on nothing more than faith, one might as well accept unseen demons.

Minute bodies did not, however, remain unseen. Already in Fracastoro's time, the use of lenses to aid vision was well established. By 1608, combinations of lenses were used to magnify distant objects and the telescope came into existence. It didn't take much of a modification to have lenses magnify tiny objects. The Italian physiologist Marcello Malpighi (1628–94) was the first to use a microscope for important work, reporting his observations in the 1650s.

The Dutch microscopist Anton van Leeuwenhoek (1632–1723) laboriously ground small but excellent lenses, which gave him a better view of the world of tiny objects than anyone else in his time had had. In 1677, he placed ditch water at the focus of one of his small lenses and found living organisms too small to see with the naked eye but each one as indisputably alive as a whale or an elephant—or as a human being. These were the one-celled animals we now call “protozoa.”

In 1683, van Leeuwenhoek discovered structures still tinier than protozoa. They were at the limit of visibility with even his best lenses, but from his sketches of what he saw, it is clear that he had discovered bacteria, the smallest cellular creatures that exist.

To do any better than van Leeuwenhoek, one had to have distinctly better microscopes and these were slow to be developed. The next microscopist to describe bacteria was the Danish biologist Otto Friedrich Müller (1730–84) who described them in a book on the subject, published posthumously, in 1786.

In hindsight, it seems that one might have guessed that bacteria represented Fracastoro's infectious agents, but there was no evidence of that and even Müller's observations were so borderline that there was no general agreement that bacteria even existed, or that they were alive if they did.

The English optician Joseph Jackson Lister (1786–1869) developed an achromatic microscope in 1830. Until then, the lenses used had refracted light into rainbows so that tiny objects were rimmed in color and could not be seen clearly. Lister combined lenses of different kinds of glass in such a way as to remove the colors.

With the colors gone, tiny objects stood out sharply and in the 1860s, the German botanist Ferdinand Julius Cohn (1828–98) saw and described bacteria with the first really convincing success. It was only with Cohn's work that the science of bacteriology was founded and that there came to be general agreement that bacteria existed.

Meanwhile, even without a clear indication of the existence of Fracastoro's agents, some physicians were discovering methods of reducing infection.

The Hungarian physician Ignaz Philipp Semmelweis (1818–65) insisted that childbed fever which killed so many mothers in childbirth, was spread by the doctors themselves, since they

went from autopsies straight to women in labor. He fought to get the doctors to wash their hands before attending the women, and when he managed to enforce this, in 1847, the incidence of childbed fever dropped precipitously. The insulted doctors, proud of their professional filth, revolted at this, however and finally managed to do their work with dirty hands again. The incidence of childbed fever climbed as rapidly as it had fallen—but that didn't bother the doctors.

The crucial moment came with the work of the French chemist Louis Pasteur (1822–95). Although he was a chemist his work had turned him more and more toward microscopes and microorganisms, and in 1865 he set to work studying a silkworm disease that was destroying France's silk industry. Using his microscope, he discovered a tiny parasite infesting the silkworms and the mulberry leaves that were fed to them. Pasteur's solution was drastic but rational. All infested worms and infested food must be destroyed. A new beginning must be made with healthy worms and the disease would be wiped out. His advice was followed and it worked. The silk industry was saved.

This turned Pasteur's interest to contagious diseases. It seemed to him that if the silkworm disease was the product of microscopic parasites other diseases might be, and thus was born the "germ theory of disease." Fracastoro's invisible infectious agents were microorganisms, often the bacteria that Cohn was just bringing clearly into the light of day.

It now became possible to attack infectious disease rationally, making use of a technique that had been introduced to medicine over half a century before. In 1798, the English physician Edward Jenner (1749–1823) had shown that people inoculated with the mild disease, cowpox, or vaccinia in Latin, acquired immunity not only to cowpox itself but also to the related but very virulent and dreaded disease, smallpox. The technique of "vaccination" virtually ended most of the devastation of smallpox.

Unfortunately, no other diseases were found to occur in such convenient pairs, with the mild one conferring immunity from the serious one. Nevertheless, with the notion of the germ theory the technique could be extended in another way.

Pasteur located specific germs associated with specific diseases, then weakened those germs by heating them or in other ways, and used the weakened germs for inoculation. Only a very

mild disease was produced but immunity was conferred against the dangerous one. The first disease treated in this way was the deadly anthrax that ravaged herds of domestic animals.

Similar work was pursued even more successfully by the German bacteriologist Robert Koch (1843–1910). Antitoxins designed to neutralize bacterial poisons were also developed.

Meanwhile, the English surgeon Joseph Lister (1827–1912), the son of the inventor of the achromatic microscope, had followed up Semmelweiss's work. Once he learned of Pasteur's research he had a convincing rationale as excuse and began to insist that, before operating, surgeons wash their hands in solutions of chemicals known to kill bacteria. From 1867 on, the practice of "antiseptic surgery" spread quickly.

The germ theory also sped the adoption of rational preventive measures—personal hygiene, such as washing and bathing; careful disposal of wastes; the guarding of the cleanliness of food and water. Leaders in this were the German scientist Max Joseph von Pettenkofer (1818–1901) and Rudolph Virchow (1821–1902). They themselves did not accept the germ theory of disease but their recommendations would not have been followed as readily were it not that others did.

In addition, it was discovered that diseases such as yellow fever and malaria were transmitted by mosquitoes, typhus fever by lice, Rocky Mountain spotted fever by ticks, bubonic plague by fleas and so on. Measures against these small germ-transferring organisms acted to reduce the incidence of the diseases. Men such as the Americans Walter Reed (1851–1902) and Howard Taylor Ricketts (1871–1910) and the Frenchman Charles J. Nicolle (1866–1936) were involved in such discoveries.

The German bacteriologist Paul Ehrlich (1854–1915) pioneered the use of specific chemicals that would kill particular bacteria without killing the human being in which it existed. His most successful discovery came in 1910, when he found an arsenic compound that was active against the bacterium that causes syphilis.

This sort of work culminated in the discovery of the antibacterial effect of sulfanilamide and related compounds, beginning with the work of the German biochemist Gerhard Domagk (1895–1964) in 1935 and of antibiotics, beginning with the work of the French-American microbiologist René Jules Dubos (1901–[1982]) in 1939.

As late as 1955 came a victory over poliomyelitis, thanks to a vaccine prepared by the American microbiologist Jonas Edward Salk (1914–[1995]).

And yet victory is not total. Right now, the once ravaging disease of smallpox seems to be wiped out. Not one case exists, as far as we know, in the entire world. There are however infectious diseases such as a few found in Africa that are very contagious, virtually 100 percent fatal, and for which no cure exists. Careful hygienic measures have made it possible for such diseases to be studied without their spreading, and no doubt effective countermeasures will be worked out.

New Disease

It would seem, then, that as long as our civilization survives and our medical technology is not shattered there is no longer any danger that infectious disease will produce catastrophe or even anything like the disasters of the Black Death and the Spanish influenza. Yet, old familiar diseases have, within them, the potentiality of arising in new forms.

The human body (and all living organisms) have natural defenses against the invasion of foreign organisms. Antibodies are developed in the bloodstream that neutralize toxins or the microorganisms themselves. White cells in the blood stream physically attack bacteria.

Evolutionary processes generally make the fight an even one. Those organisms more efficient at self-protection against microorganisms tend to survive and pass on their efficiency to their offspring. Nevertheless, microorganisms are far smaller even than insects and far more fecund. They evolve much more quickly, with individual microorganisms almost totally unimportant in the scheme of things.

Considering the uncounted numbers of microorganisms of any particular species that are continually multiplying by cell fission, large numbers of mutations must be produced just as continually. Every once in a while such a mutation may act to make a particular disease far more infectious and deadly. Furthermore, it may sufficiently alter the chemical nature of the microorganism so that the antibodies which the host organism is capable of manufac-

turing are no longer usable. The result is the sudden onslaught of an epidemic. The Black Death was undoubtedly brought about by a mutant strain of the microorganism causing it.

Eventually, though, those human beings who are most susceptible die, and the relatively resistant survive, so that the virulence of the diseases dies down. In that case, is the human victory over the pathogenic microorganism permanent? Might not new strains of germs arise? They might and they do. Every few years a new strain of flu rises to pester us. It is possible, however, to produce vaccines against such a new strain once it makes an appearance. Thus, when a single case of “swine flu” appeared in 1976, a full scale mass-vaccination was set in action. It turned out not to be needed, but it showed what could be done. ■

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Isaac Asimov (1920–1992) *was a legendary American author and biochemist who wrote science fiction and popular science books. He wrote or edited about 500 volumes, of which the most famous are those in the Foundation and Robot series.*

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Products:

Will COVID-19 Pave the Way For DIY Precision Medicine?

By Linda Marsa



It looks like an ordinary toilet but it is anything but. The “smart toilet” is the diagnostic tool of the future, equipped with cameras that take snapshots of the users and their waste, motion sensors to analyze what’s inside the urine and stool samples, and software that automatically sends data to a secure, cloud-based system that can be easily accessed by your family doctor. Using urine “dipstick tests” similar to the home pregnancy strips, the smart toilet can detect certain proteins, immune system biomarkers and blood cells that indicate the presence of such diseases as infections, bladder cancer, and kidney failure.

The rationale behind this invention is that some of the best ways of detecting what’s going on in our bodies is by analyzing the substances we excrete every day, our sweat, urine, saliva and yes, our feces. Instead of getting sporadic snapshots from doctor’s visits once or twice a year, the smart toilet provides continuous monitoring of our health 24/7, so we can catch the tell-tale molecular signature of illnesses at their earliest and most treatable stages. A brainchild of Stanford University researchers, they’re now working to add a COVID-19 detection component to their suite of technologies—corona virus particles can be spotted in stool samples—and hope to have the system available within the year.

“We can connect the toilet system to cell phones so we’ll know the results within 30 minutes,” says Seung-min Park, a lead investigator on the research team that devised this technology and a senior research scientist at the Stanford University School of Medicine. “The beauty of this technology is that it can continuously monitor even after this pandemic is over. It’s a way of doing community surveillance. If there is a second wave of infections in the future, we’ll know right away.”

Experts believe that the COVID-19 pandemic will accelerate the widespread acceptance of in-home diagnostic tools such as this. “Shock events” like pandemics can be catalysts for sweeping changes in society, history shows us. The Black Death marked the end of feudalism and ushered in the Renaissance while the aftershocks of the Great Depression and two world wars in the 20th century led to the social safety net of the New Deal and NATO and the European Union. COVID-19 could fundamentally alter the way we deliver healthcare, abandoning the outdated 20th century brick and mortar fee-for-service model in favor of digital medicine. At-home diagnostics may be the leading edge of this seismic shift and the pandemic could accelerate the product innovations that allow for home based medical screening.

“That’s the silver lining to this devastation,” says Dr. Leslie Saxon, executive director of the USC Center for Body Computing at the Keck School of Medicine in Los Angeles. As an interventional cardiologist, Saxon has spent her career devising and refining the implantable and wearable wireless devices that are used to treat and diagnose heart conditions and prevent sudden death. “This will open up innovation—research has been stymied by a lack of imagination and marriage to an antiquated model,” she adds. “There are already signs this is happening—relaxing state laws about licensure, allowing physicians to deliver health care in non-traditional ways. That’s a real sea change and will completely democratize medical information and diagnostic testing.”

Ironically, diagnostics have long been a step-child of modern medicine, even though accurate and timely diagnostics play a crucial role in disease prevention, detection and management. “The delivery of health care has proceeded for decades with a blind spot: diagnostic errors—inaccurate or delayed diagnoses—persist throughout all settings of care and continue to harm an unacceptable number of patients,” according to a 2015 National Academy of Medicine report. That same report found as many as one out of five adverse events in the hospital result from these errors and

they contribute to 10 percent of all patient deaths. The pandemic should alter the diagnostic landscape. We already have a wealth of wearable and implantable devices, like glucose sensors to monitor blood sugar levels for diabetics, Apple’s smart watch, electrocardiogram devices that can detect heart arrhythmias, and heart pacemakers.

The Food and Drug Administration is working closely with in-home test developers to make accurate COVID-19 diagnostic tools readily available and has so far greenlighted three at-home collection test kits. Two, LabCorp’s and Everlywell’s, use nasal swabs to take samples. The third one is a spit test, using saliva samples, that was devised by a Rutgers University laboratory in partnership with Spectrum Solutions and Accurate Diagnostic Labs.

In fact, DIY diagnostic company Everlywell, an Austin, Texas-based digital health company, already offers more than 30 at-home kits for everything from fertility to food sensitivity tests. Typically, consumers collect a saliva or finger-prick blood sample, dispatch it in a pre-paid shipping envelope to a laboratory, and a physician will review the results and send a report to consumers’ smartphones.

Thanks to advances in technology, samples taken at home can now be preserved long enough to arrive intact at diagnostic laboratories. The key is showing the agency “transport and shipping don’t change or interfere with the integrity of the samples,” says Dr. Frank Ong, Everlywell’s chief medical and scientific officer.

Ong is keenly aware of the importance of saturation testing because of the lessons learned by colleagues fighting the SARS pandemic in his family’s native Taiwan in 2003. “In the beginning, doctors didn’t know what they were dealing with and didn’t protect themselves adequately,” he says. “But over two years, they learned the hard way that there needs to be enough testing, contact tracing of those who have





been exposed, and isolation of people who test positive. The value of at-home testing is that it can be done on the kind of broad basis that needs to happen for our country to get back to work.”

Because of the pandemic, new policies have removed some of the barriers that impeded the widespread adoption of home-based diagnostics and telemedicine. Physicians can now practice across state lines, get reimbursed for telemedicine visits and use Face Time to communicate with their patients, which had long been considered taboo because of privacy issues. Doctors and patients are becoming more comfortable and realizing the convenience and benefits of being able to do these things virtually.

Added to this, the only way to safely reopen for business without triggering a second and perhaps even more deadly wave of sickness is through large scale testing, but hospitals and doctors’ offices are no longer the safest places. “We don’t want people sitting in a waiting room who later find out they’re positive, and potentially infected everyone, including doctors and nurses,” says Dr. Kavita Patel, a physician in Washington, DC who served as a policy director in the Obama White House.

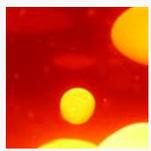
In-home testing avoids the risks of direct exposure to the virus for both patients and health care professionals, who can dispense with cumbersome protective gear to take samples, and also enables people without reliable transportation or child-care to learn their status. “At home testing can be a critical component of our country’s overall testing strategy,” says Dr. Shantanu Nundy, chief medical officer at Accolade Health and on the faculty of the Milken Institute School of Public Health at George Washington University. “Once we’re back at work, we need to be much more targeted, and have much more access to data and controlling those outbreaks as tightly as possible. The best way to do that is by leapfrogging clinics and being able to deliver tests at home for people who are disenfranchised by the current system.”

In the not too distant future, in-home diagnostics could be a key component of precision medicine, which is customized care tailored specifically to each patient’s individual needs. Like Stanford’s smart toilet prototype, these ongoing surveillance tools will gather health data, ranging from exposures to toxins and pollutions in the environment to biochemical activity, like rising blood pressure, signs of inflammation, failing kidneys or tiny cancerous tumors, and provide continuous real time information.

“These can be deeply personalized and enabled by smart phones, sensors and artificial intelligence,” says USC’s Leslie Saxon. “We’ll be seeing the floodgates opening to patients accessing medical services through the same devices that they access other things, and leveraging these tools for our health and to fine tune disease management in a model of care that is digitally enabled.” ■

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Linda Marsa is a contributing editor at Discover whose work has been featured in Best American Science Writing. She is also a former Los Angeles Times reporter and author of *Fevered: Why a Hotter Planet Will Harm Our Health and How We Can Save Ourselves*.



8

Politicians:
**Will the
Pandemic
Propel STEM
Experts
to Political
Power?**

By Randy Dotina



If your car won't run, you head to a mechanic. If your faucet leaks, you contact a plumber. But what do you do if your politics are broken? You call a... lawyer. That's been the American way since the beginning. Thousands of members of the House and Senate have been attorneys, along with nearly two dozen U.S. presidents from John Adams to Abraham Lincoln to Barack Obama. But a band of STEM professionals is changing the equation. They're hoping anger over the coronavirus pandemic will turn their expertise into a political superpower that propels more of them into office.

"This could be a turning point, part of an acceleration of something that's already happening," said Nancy Goroff, a New York chemistry professor who's running for a House seat in Long Island and will apparently be the first female scientist with a Ph.D. in Congress. "Scientists have been more engaged with politics over the past three years amid a consistent sidelining of science and expertise, and now the pandemic has crystalized things even more."

Professionals in the science, technology, engineering and medicine (STEM) fields don't have an easy task, however. To succeed, they must find ways to engage with voters instead of their usual target audiences — colleagues, patients and students. And they'll need to beat back a long-standing political tradition that has made federal and state politics a domain of attorneys and businesspeople, not nurses and biologists.

In the 2017-2018 Congress, more members of Congress said they'd worked as radio talk show hosts (seven) and as car dealership owners (six) than scientists (three — a physicist, a microbiologist, and a chemist), according to a 2018 report from the Congressional Research Service. There were more bankers (18) than physicians (14), more management consultants (18) than engineers (11), and more former judges (15) than dentists (4), nurses (2), veterinarians (3), pharmacists (1) and psychologists (3) combined.

In 2018, a "STEM wave" brought nine members with STEM backgrounds into office. But those with initials like PhD, MD and RN after their names are still far outnumbered by Esq. and MBA types.



Why the gap? Astrophysicist Rush Holt Jr., who served from 1999-2015 as a House representative from New Jersey, thinks he knows. "I have this very strong belief, based on 16 years in Congress and a long, intense public life, that the problem is not with science or the scientists," said. "It has to do with the fact that the public just doesn't pay attention to science. It never occurs them that they have any role in the matter."

But Holt, former chief executive of the American Association for the Advancement of Science, believes change is on the way. "It's likely that the pandemic will affect people's attitudes," former congressman Holt said, "and lead them to think that they need more scientific thinking in policy-making and legislating." Holt's father was a U.S. senator from West Virginia, so he grew up with a political education. But how can scientists and medical professionals succeed if they have no background in the art of wooing voters?

That's where an organization called 314 Action comes in. Named after the first three digits of pi, 314 Action declares itself to be the "pro-science resistance" and says it's trained more than 1,400 scientists to run for public office.

In 2018, 9 out of 13 House and Senate candidates endorsed by the group won their races. In 2020, 314 Action is endorsing 12 candidates for the House (including an engineer), four for the Senate (including an astronaut) and one for governor (a mathematician in Kansas). It expects to spend \$10 million-\$20 million to support campaigns this year.

"Physicians, scientists and engineers are problem-solvers," said Shaughnessy Naughton, a Pennsylvania chemist who founded 314 Action after an unsuccessful bid for Congress. "They're willing to dive into issues, and their skills would benefit policy decisions that extend way beyond their scientific fields of expertise."

Like many political organizations, 314 Action focuses on teaching potential candidate how to make it in politics, aiming to help them drop habits that fail to bridge the gap between scientists and civilians. "Their first impulse is not to tell a story," public speaking coach Chris Jahnke told the public radio show "Marketplace" in 2018. "They would rather start with a stat." In a training session, Jahnke aimed to teach them to do both effectively.

"It just comes down to being able to speak about general principles in regular English, and to always have the science intertwined with basic human values," said Rep. Kim Schrier, a Washington state pediatrician who won election to Congress in 2018.

She believes her experience on the job has helped her make connections with voters. In a chat with parents about vaccines for their child, for example, she knows not to directly jump into an arcane discussion of case-control studies.

The best alternative, she said, is to "talk about how hard it is to be a parent making these decisions, feeling scared and worried. Then say that you've looked at the data and the research, and point out that pediatricians would never do anything to hurt children because we want to do everything that is good for them. When you speak heart to heart, it gets across the message and the credibility of medicine and science."

Communication skills will be especially important if the pandemic spurs more Americans to focus on politics and the records of incumbents in regard to matters like public health and climate change. Thousands of candidates will have to address the nation's coronavirus response, and a survey commissioned by 314 Action suggests that voters may be receptive to those with STEM backgrounds. The poll, of 1,002 likely voters in early April 2020, found that 41%-46% of those surveyed said they'd be "much more favorable" toward candidates who were doctors, nurses, scientists and public health professionals. Those numbers were the highest in the survey compared to just 9% for lawyers.

The pandemic "will hopefully awaken people and trigger a change that puts science, medicine and public health on a pedestal where science is revered and not dismissed as elitist," Dr. Schrier said. "It will come from a recognition that what's going to get us out of this bind are scientists, vaccine development and the hard work of the people in public health on the ground." ■

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Randy Dotinga is a freelance journalist based in San Diego and former president of the American Society of Journalists & Authors.

A NEW FUTURE

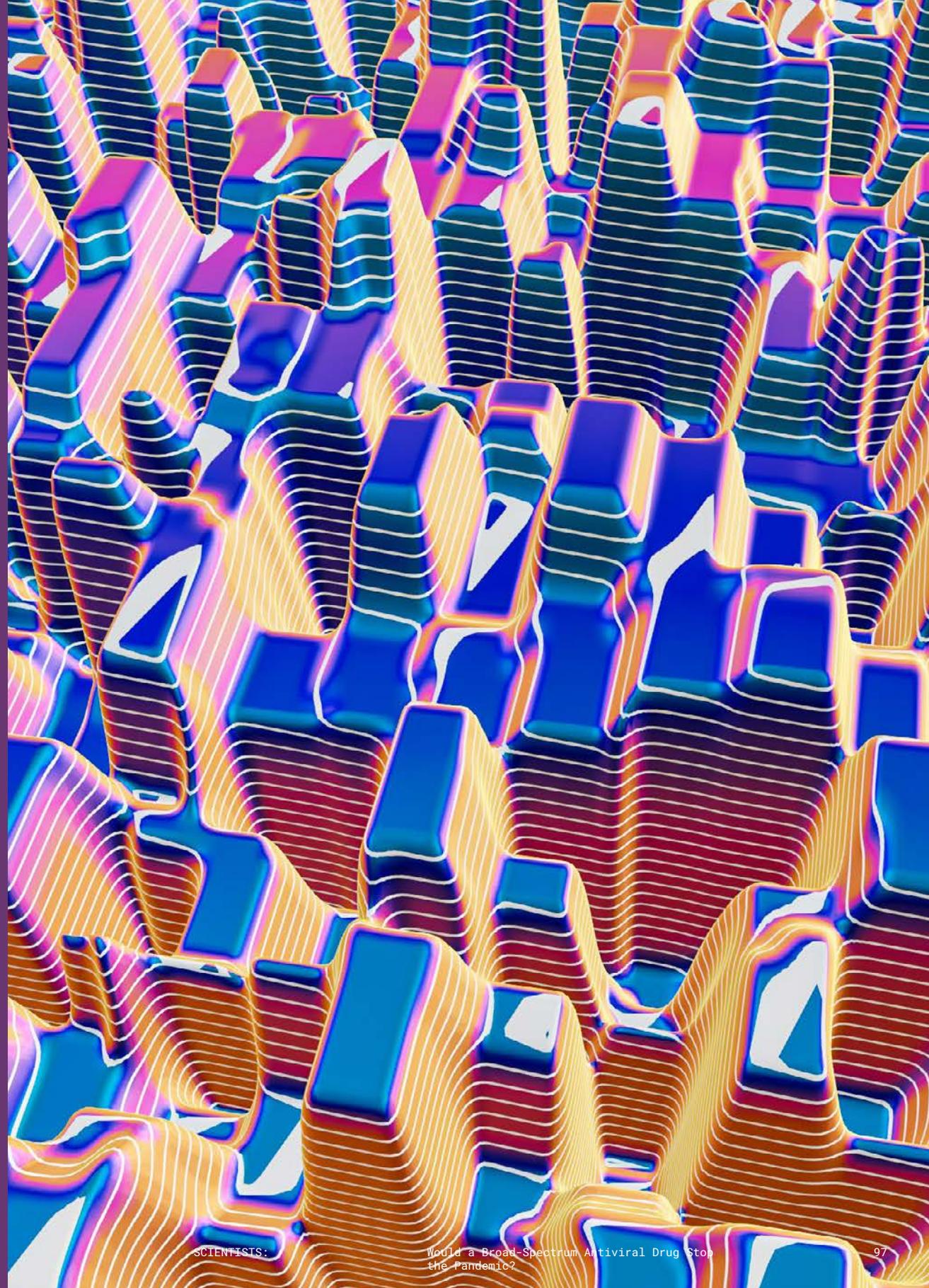
9



Scientists:

Would a Broad-Spectrum Antiviral Drug Stop the Pandemic?

By Bob Roehr



The refocusing of medical research to COVID-19 is unprecedented in human history. Six months ago, we barely were aware that the virus existed, and now a torrent of new information greets us each day online.

Clinicaltrials.gov, the most commonly used registry for worldwide medical research, listed 1358 clinical trials on the disease, including using scores of different potential drugs and multiple combinations, when I first wrote this sentence. The following day that number of trials had increased to 1409. Laboratory work to prepare for trials presents an even broader and untabulated scope of activity.

Most trials will fail or not be as good as what has been discovered in the interim, but the hope is that a handful of them will yield vaccines for prevention and treatments to attenuate and ultimately cure the deadly infection.

The first impulse is to grab whatever drugs are on the shelf and see if any work against the new foe. We know their safety profiles and they have passed some regulatory hurdles. Remdesivir is the first to register some success against SARS-CoV-2, the virus behind the disease. The FDA has granted it expedited-use status, pending presentation of data that may lead to full approval of the drug.

Most observers see it as a treatment that might help, but not one that by itself is likely to break the back of the pandemic. Part of that is because it is delivered though IV infusion, which requires hospitalization, and as with most antiviral drugs, appears to be most beneficial when started early in disease. “The most effective products are going to be that ones that are developed by actually understanding more about this coronavirus,” says Margaret “Peggy” Hamburg, who once led the New York City public health department and later the U.S. Food and Drug Administration.

Combination therapy that uses different drugs to hit a virus at different places in its life cycle have proven to work best in treating HIV and hepatitis C, and likely will be needed with this virus as well. Most viruses are simply too facile at evolving resistance to a single drug, and so require multiple hits to keep them down.

Laboratory work suggests that other drugs, both off-the-shelf and in development, particularly those to treat HIV and hepatitis, might also be of some benefit against SARS-CoV-2. But the number of possible drug combinations is mind-bogglingly large and the capacity to test them all right now is limited.

Broad-Spectrum Antivirals

Viruses are simple quasi-life forms. Effective treatments are more likely to be specific to a given virus, or at best its close relatives. That is unlike bacteria, where broad-spectrum antibiotics often can be used against common elements like the bacterial cell wall, or can disrupt quorum sensing signals that bacteria use to function as biofilms.

More than a decade ago, virologist Benhur Lee’s lab at UCLA (now at Mt. Sinai in New York City) stumbled upon a broad-spectrum antiviral approach that seemed to work against all enveloped viruses they tested. The list ranged from the common flu to HIV to Ebola.

Other researchers grabbed this lead to develop a compound that worked quite well in cell cultures, but when they tried it in animals, a frustrating snag emerged; the compound needed to be activated by light. As the greatest medical need is to counter viruses deep inside the body, the research was put on the shelf. So Lee was surprised to learn recently that a company has inquired about rights to develop the compound not as a treatment but as a possible

disinfectant. The tale illustrates both the unanticipated difficulties of drug development and that one never knows how knowledge ultimately might be put to use.

Remdesivir is a failed drug for Ebola that has found new life with SARS-CoV-2. It targets polymerase, an enzyme that the virus produces to use host cell machinery to replicate itself, and since the genetic sequence of polymerase is very similar among all of the different coronaviruses, scientists hope that the drug might be useful against known members of the family and others that might emerge in the future.

But nature isn’t always that simple. Viral RNA is not a two-dimensional assemblage of genes in a flat line on a table; rather it is a three-dimensional matrix of twists and turns where a single atom change within the polymerase gene or another gene close by might change the orientation of the RNA or a molecular arm within it and block a drug from accessing the targeted binding site on the virus. One drug might need to bind to a large flat surface, while another might be able to slip a dagger-like molecular arm through a space in the matrix to reach its binding target.

That is why a broad-spectrum antiviral is so hard to develop, and why researchers continue to work on a wide variety of compounds that target polymerase as a binding site.

Additionally, it has taken us decades to begin to recognize the unintended consequences of broad-spectrum rather than narrowly targeted antibiotics on the gut microbiome and our overall health. Will a similar issue potentially arise in using a broad-spectrum antiviral?

“Off-target side effects are always of concern with drugs, and antivirals are no exception,” says Yale University microbiologist Ben Chen. He believes that “most” bacteriophages, the viruses that infect bacteria and likely help to maintain stability in the gut microbial ecosystem, will shrug off such a drug. However,

a few families of phages share polymerases that are similar to those found in coronaviruses. While the immediate need for treatment is great, we will have to keep a sharp eye out for unanticipated activity in the body’s ecosystem from new drugs.

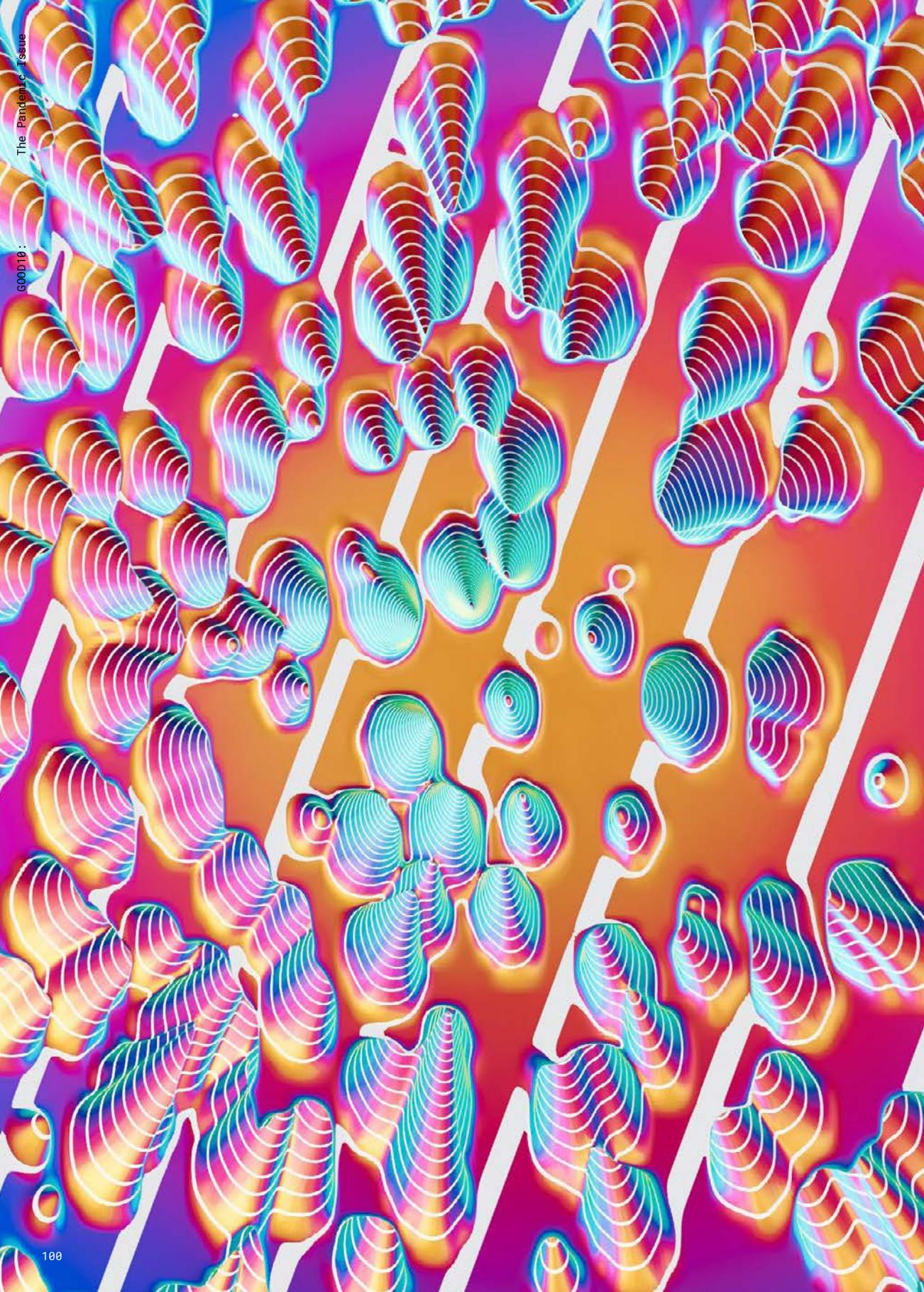
Is an Antiviral Needed?

There are many unanswered questions about COVID-19, but perhaps the most fascinating is whether we even need to directly go after the virus itself. Mounting evidence indicates that up to half the people who contract the infection don’t seem to experience significant symptoms and their immune system seems to clear the virus.

The most severe cases of COVID-19 appear to result from an overactive immune response that damages surrounding tissue. Perhaps downregulating that response will be sufficient to reduce the disease burden. Several studies are underway using approved antibodies that modulate an overly active immune response.

One of the most surprising findings to date involves the monoclonal antibody leronlimab. It was originally developed to treat HIV infection and works modestly well there, but other drugs are better and its future likely will be mainly to treat patients who have developed resistance to those other drugs.

The response has been amazingly different in patients in the U.S. with COVID-19 who were given emergency access to leronlimab – two injections a week apart, though the company believes that four might be better. The immune response and inflammatory cytokines declined significantly, T cell counts were maintained, and surprisingly the amount of virus in the blood declined too. Data from the first ten patients is available in a preprint while the paper undergoes peer review



for publication. Data from an additional fifty patients will be added.

“We got lucky and hit the bulls’ eye from a mile away,” says Jay Lalezari, the chief science officer of Cytodyn, the company behind leronlimab. Dr. Jay, as he is widely known in San Francisco, built an adoring fan base running many of the early-phase drug studies for treating HIV. While touting leronlimab, Lalezari suspects it might best be used as part of a combination therapy.

The small, under-capitalized firm is struggling for attention in the vast pool of therapies proposed to treat COVID-19. It faces the added challenge of gaining acceptance because it is based on a different approach and mechanism of action, which involves a signaling molecule important to immune cell migration, than what most researchers and the FDA anticipate as being relevant to counter SARS-CoV-2.

Common Issues

All of the therapeutics under development will face some common sets of issues. One is the pressure to have results yesterday, because people are dying. The rush to disseminate information “make me worry that certain things will become entrenched as truth, even in the scientific community, without the actual scientific documentation that ordinarily scientists would demand,” says Hamburg.

Lack of standardization in assays and laboratory operations makes it difficult to compare results between labs studying SARS-CoV-2. In the long run, this will slow down the iterative process of research that builds upon what has gone before. And the shut down of supply chains, from chemicals to cell lines to animals to air shipment, has the potential to further hobble research.

Almost all researchers consult with the FDA in putting together their clinical trials. But the agency is overwhelmed with the surge of activity in the field, and is

even less capable of handling novel approaches that fall outside of its standard guidance.

“It is becoming increasingly clear that the biggest problem for drug and vaccine makers is not which therapeutics or vaccine platform to pursue. It is that conventional clinical development paths are far too lengthy and cumbersome to address the current public health threat,” John Hodgson wrote in *Nature Biotechnology*.

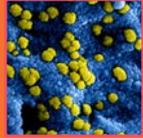
Another complicating factor with this virus is the broad range of organ and tissue types it can infect. That has implications for potential therapies, which often vary in their ability to enter different tissues. At a minimum, it complicates the drug development process.

Remdesivir has become the de facto standard of care. Ideally, clinical trials are conducted using the existing standard of care rather than a placebo as the control group. But shortages of the drug make that difficult and further inhibit learning what is the best treatment regimen for regular clinical care.

“Understandably, we all really want to respond to COVID-19 in a much, much more accelerated fashion,” says Hamburg. But ultimately that depends upon “the reality of understanding the nature of the disease. And that is going to take a bit more time than we might like or wish.” ■

Bob Roehr is a biomedical journalist based and Washington, D.C. and author of the prize-winning *leapsmag* article about the world’s first known person who overcame HIV without medical intervention.

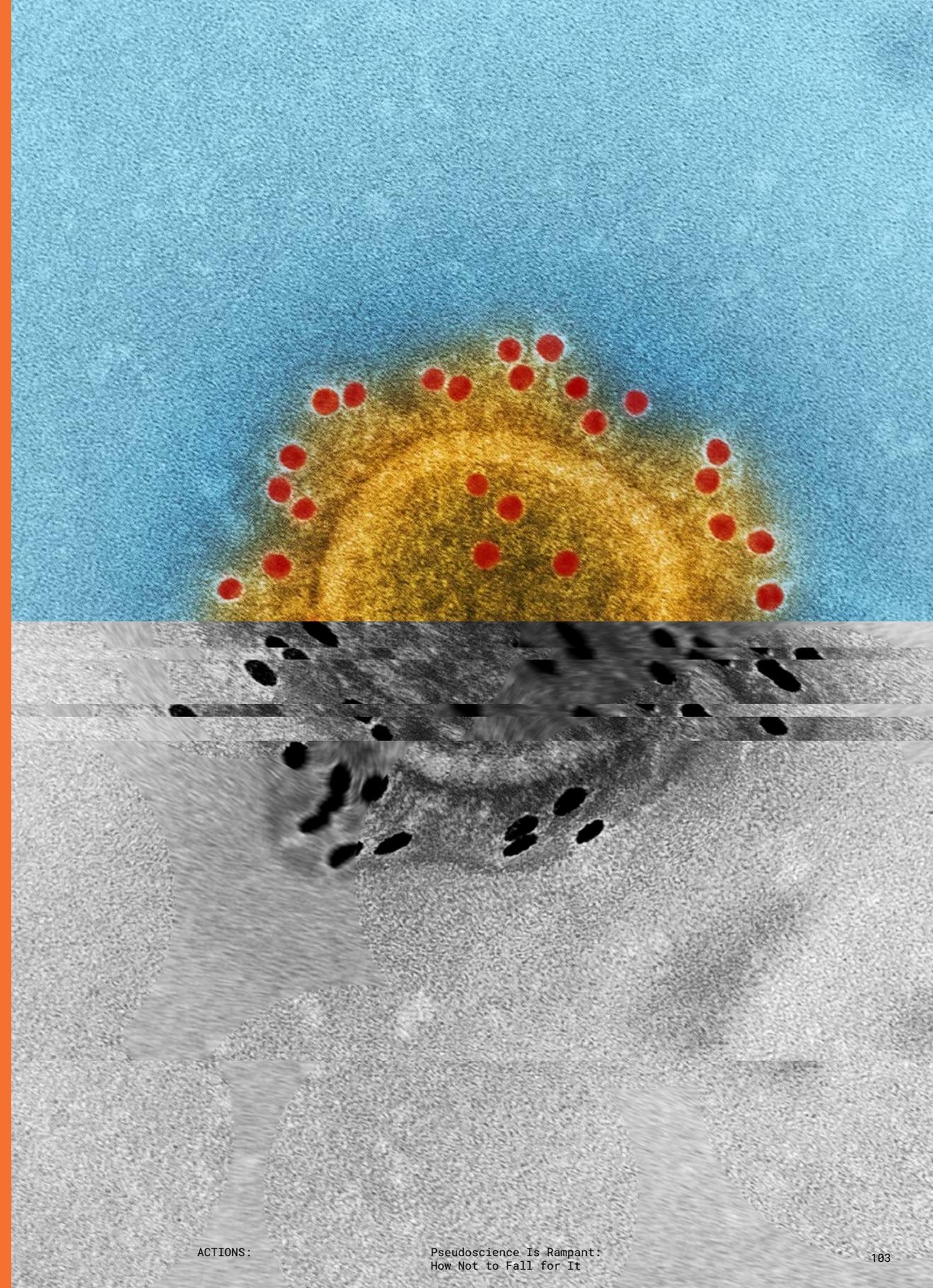
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Actions:

Pseudoscience Is Rampant: How Not to Fall for It

Stuart Firestein



Whom to believe?

The relentless and often unpredictable coronavirus (SARS-CoV-2) has, among its many quirky terrors, dredged up once again the issue that will not die: science versus pseudoscience. The scientists, experts who would be the first to admit they are not infallible, are now in danger of being drowned out by the growing chorus of pseudoscientists, conspiracy theorists, and just plain troublemakers that seem to be as symptomatic of the virus as fever and weakness.

How is the average citizen to filter this cacophony of information and misinformation posing as science alongside real science? While all that noise makes it difficult to separate the real stuff from the fakes, there is at least one positive aspect to it all.

A famous aphorism by one Charles Caleb Colton, a popular 19th-century English cleric and writer, says that “imitation is the sincerest form of flattery.”

The frauds and the paranoid conspiracy mongers who would perpetrate false science on a susceptible public are at least recognizing the value of science—they imitate it. They imitate the ways in which science works and make claims as if they were scientists, because even they recognize the power of a scientific approach. They are inadvertently showing us how much we value science. Unfortunately they are just shabby counterfeits.

Separating real science from pseudoscience is not a new problem. Philosophers, politicians, scientists, and others have been worrying about this perhaps since science as we know it, a science based entirely on experiment and not opinion, arrived in the 1600s. The original charter of the British Royal Society, the first organized scientific society, stated that at their formal meetings there would be no discussion of politics, religion, or perpetual motion machines.

The first two of those for the obvious purpose of keeping the peace. But the third is interesting because at that time perpetual motion machines were one of the main offerings of the imitators, the bogus scientists who were sure that you could find ways around the universal laws of energy and make a buck on it. The motto adopted by the society was, and remains, *Nullius in verba*, Latin for “take nobody’s word for it.” Kind of an early version of Missouri’s venerable state motto: “Show me.”

You might think that telling phony science from the real thing wouldn’t be so difficult, but events, historical and current, tell a very different story—often with tragic outcomes. Just one terrible example is the estimated 350,000 additional HIV deaths in South Africa directly caused by the now-infamous conspiracy theories of their own elected President no less (sound familiar?). It’s surprisingly easy to dress up phony science as the real thing by simply adopting, or appearing to adopt, the trappings of science.

Thus, the anti-vaccine movement claims to be based on suspicion of authority, beginning with medical authority in this case, stemming from the fraudulent data published by the now-disgraced Andrew Wakefield, an English gastroenterologist. And it’s true that much of science is based on suspicion of authority. Science got its start when the likes of Galileo and Copernicus claimed that the Church, the State, even Aristotle, could no longer be trusted as authoritative sources of knowledge.

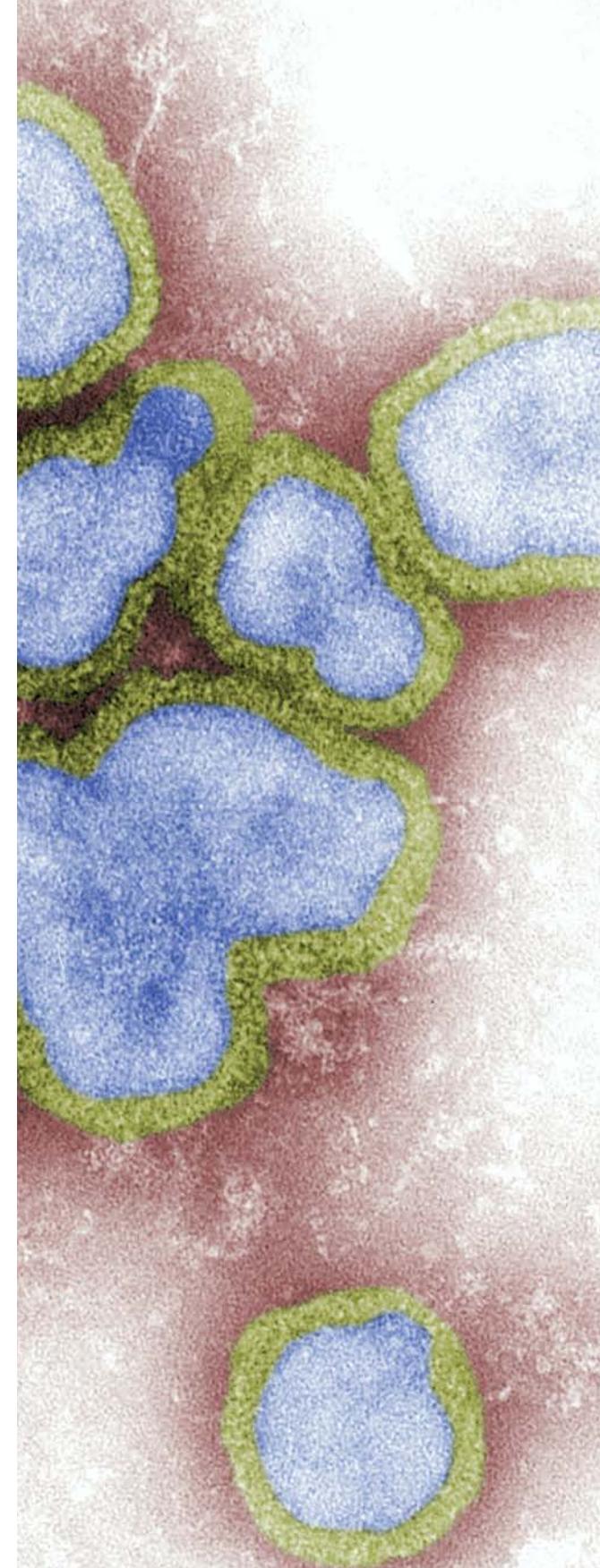
But Galileo and those who followed him produced alternative explanations, and those alternatives were based on data that arose independently from many sources and generated a great deal of debate and, most importantly, could be tested by experiments that could prove them wrong. The anti-vaccine movement imitates science, still citing the discredited Wakefield report, but really offers nothing but suspicion—and that is paranoia, not science.

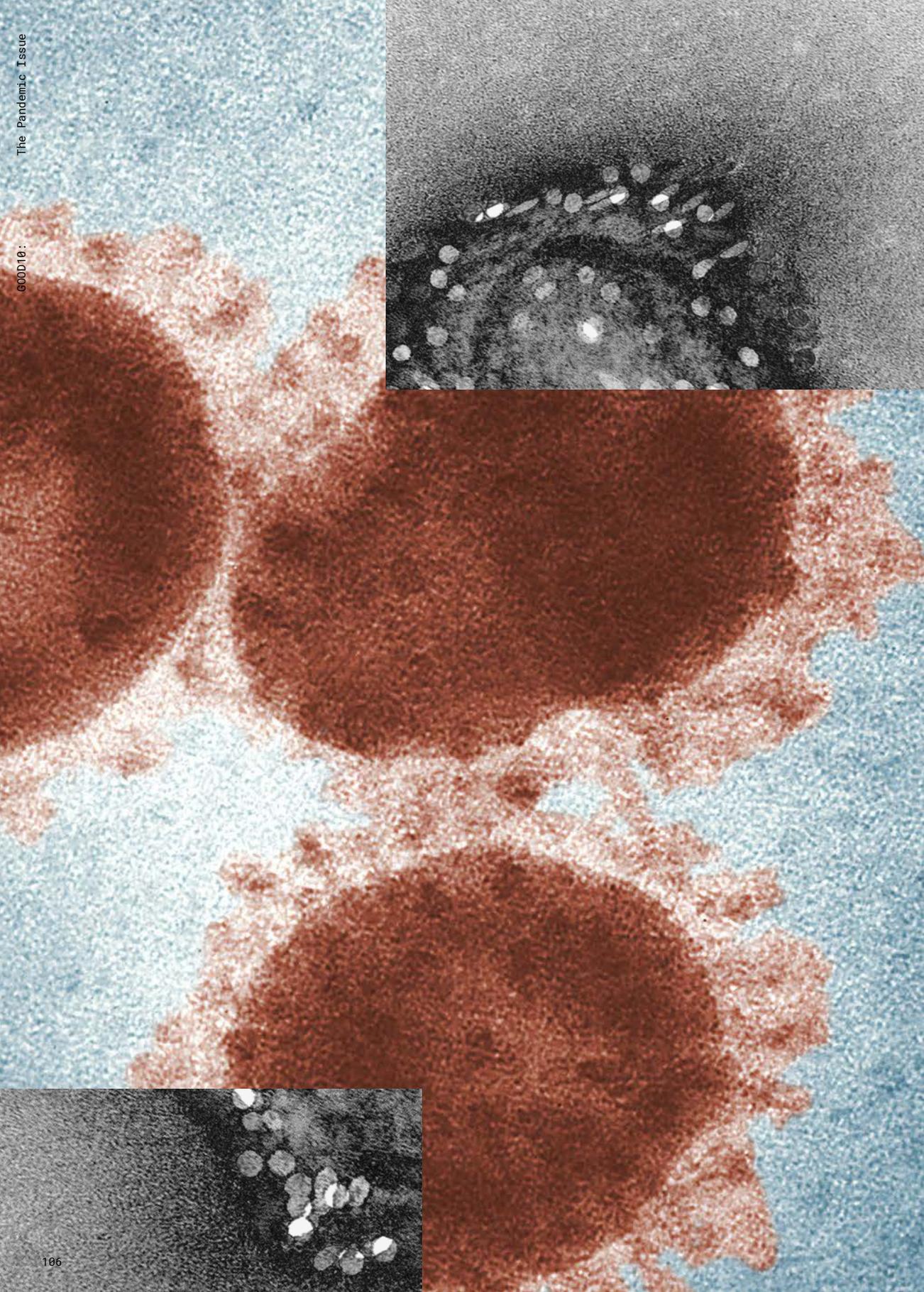
Similarly, there are those who try to cloak their nefarious motives in the trappings of science by claiming that they are taking the scientific posture of doubt. Science after all depends on doubt—every scientist doubts every finding they make. Every scientist knows that they can’t possibly foresee all possible instances or situations in which they could be proven wrong, no matter how strong their data. Einstein was doubted for two decades, and cosmologists are still searching for experimental proofs of relativity. Science indeed progresses by doubt. In science revision is a victory.

But the imitators merely use doubt to suggest that science is not dependable and should not be used for informing policy or altering our behavior. They claim to be taking the legitimate scientific stance of doubt. Of course, they don’t doubt everything, only what is problematic for their individual enterprises. They don’t doubt the value of blood pressure medicine to control their hypertension. But they should, because every medicine has side effects and we don’t completely understand how blood pressure is regulated and whether there may not be still better ways of controlling it. But we use the pills we have because the science is sound even when it is not completely settled. Ask a hypertensive oil executive who would like you to believe that climate science should be ignored because there are too many uncertainties in the data, if he is willing to forgo his blood pressure medicine—because it, too, has its share of uncertainties and unwanted side effects.

The apparent success of pseudoscience is not due to gullibility on the part of the public. The problem is that science is recognized as valuable and that the imitators are unfortunately good at what they do. They take a scientific pose to gain your confidence and then distort the facts to their own purposes. How does one learn to spot the con without getting a Ph.D. and spending years in a laboratory?

What can be done to make the distinction clearer? Several solutions have been tried—and seem to have failed. Radio and television shows about the latest sci-





entific breakthroughs are a noble attempt to give the public a taste of good science, but they do nothing to help you distinguish between them and the pseudoscience being purveyed on the neighboring channel and its “scientific investigations” of haunted houses.

Similarly, attempts to inculcate what are called “scientific habits of mind” are of little practical help. These habits of mind are not so easy to adopt. They invariably require some amount of statistics and probability and much of that is counterintuitive—one of the great values of science is to help us to counter our normal biases and expectations by showing that the actual measurements may not bear them out.

Additionally, there is math—no matter how much you try to hide it, much of the language of science is math (Galileo said that). And half the audience is gone with each equation (Stephen Hawking said that). It’s hard to imagine a successful program of making a non-scientifically trained public interested in adopting the rigors of scientific habits of mind. Indeed, I suspect there are some people, artists for example, who would be rightfully suspicious of changing their thinking to being habitually scientific. Many scientists are frustrated by the public’s inability to think like a scientist, but in fact it is neither easy nor always desirable to do so. And it is certainly not practical.

There is a more intuitive and simpler way to tell the difference between the real thing and the cheap knock-off. In fact, it is not so much intuitive as it is counterintuitive, so it takes a little bit of mental work. But the good thing is it works almost all the time by following a simple, if as I say, counterintuitive, rule.

True science, you see, is mostly concerned with the unknown and the uncertain. If someone claims to have the ultimate answer or that they know something for certain, the only thing for sure is that they are trying to fool you. Mystery and uncertainty may not strike you right off as desirable or strong traits, but that is precisely where one finds the creative solutions that science has historically arrived at. Yes, science ac-

cumulates factual knowledge, but it is at its best when it generates new and better questions. Uncertainty is not a place of worry, but of opportunity. Progress lives at the border of the unknown.

How much would it take to alter the public perception of science to appreciate unknowns and uncertainties along with facts and conclusions? Less than you might think. In fact, we make decisions based on uncertainty every day—what to wear in case of 60 percent chance of rain—so it should not be so difficult to extend that to science, in spite of what you were taught in school about all the hard facts in those giant textbooks.

You can believe science that says there is clear evidence that takes us this far... and then we have to speculate a bit and it could go one of two or three ways—or maybe even some way we don’t see yet. But like your blood pressure medicine, the stuff we know is reliable even if incomplete. It will lower your blood pressure, no matter that better treatments with fewer side effects may await us in the future.

Unsettled science is not unsound science. The honesty and humility of someone who is willing to tell you that they don’t have all the answers, but they do have some thoughtful questions to pursue, are easy to distinguish from the charlatans who have ready answers or claim that nothing should be done until we are an impossible 100-percent sure.

Imitation may be the sincerest form of flattery. The problem, as we all know, is that flattery will get you nowhere. ■

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Stuart Firestein is Professor and former Chair of the Department of Biological Sciences at Columbia University in New York. He is the author of *Ignorance and How it Drives Science* (2012) and *Failure: Why Science Is So Successful* (2014), both from Oxford University Press.

10b



Actions:

How COVID-19 Could Usher in a New Age of Collective Drug Discovery

By David Cox



By mid-March, Alpha Lee was growing restless. A pioneer of AI-driven drug discovery, Lee leads a team of researchers at the University of Cambridge, but his lab had been closed amidst the government-initiated lockdowns spreading inexorably across Europe.

Having spoken to his collaborators across the globe – many of whom were seeing their own experiments and research projects postponed indefinitely due to the pandemic – he noticed a similar sense of frustration and helplessness in the face of COVID-19.

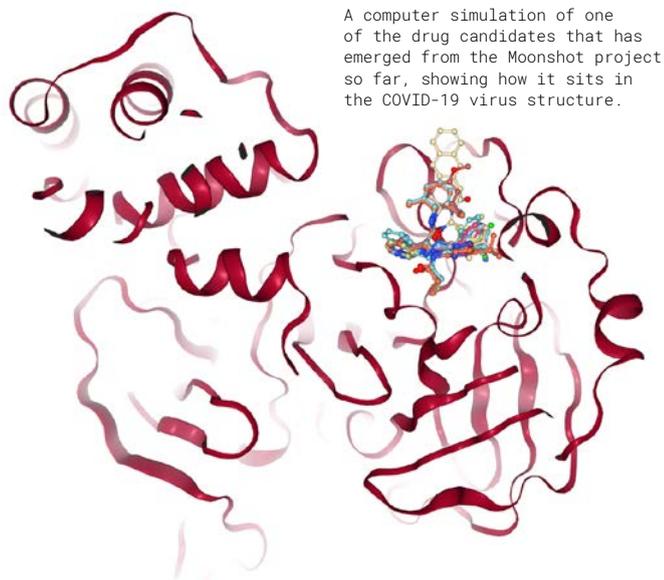
While colleagues talked about finding a novel treatment for the virus, Lee was well aware the process was likely to be long and laborious. Traditional methods of drug discovery risked suffering the same fate as the efforts to find a cure for SARS in the early 2000s, which took years and were ultimately abandoned long before a drug ever reached the market.

To avoid such an outcome, Lee was convinced that global collaboration was required. Together with a collection of scientists in the U.K. and Canada, he launched the ‘COVID Moonshot’ – a project which encouraged chemists worldwide to share their ideas for potential drug designs. If the Moonshot proves successful, they hope it could serve as a future benchmark for finding new medicines for chronic diseases.

Solving a Complex Jigsaw

In February, ShanghaiTech University published the first detailed snapshots of the proteins of the SARS-CoV-2 coronavirus using a technique called X-ray crystallography. In particular, they revealed a high-resolution profile of the virus’s main protease – the part of its structure which enables it to replicate inside a host – and the main drug target. The images were tantalizing.

“We could see all the tiny pieces sitting in the structure like pieces of a jigsaw,” said Lee. “All we needed was for someone to come up with the best idea of joining these pieces together with a drug. Then you’d be left with a strong molecule which sits in the protease, and stops it from working, killing the virus in the process.”



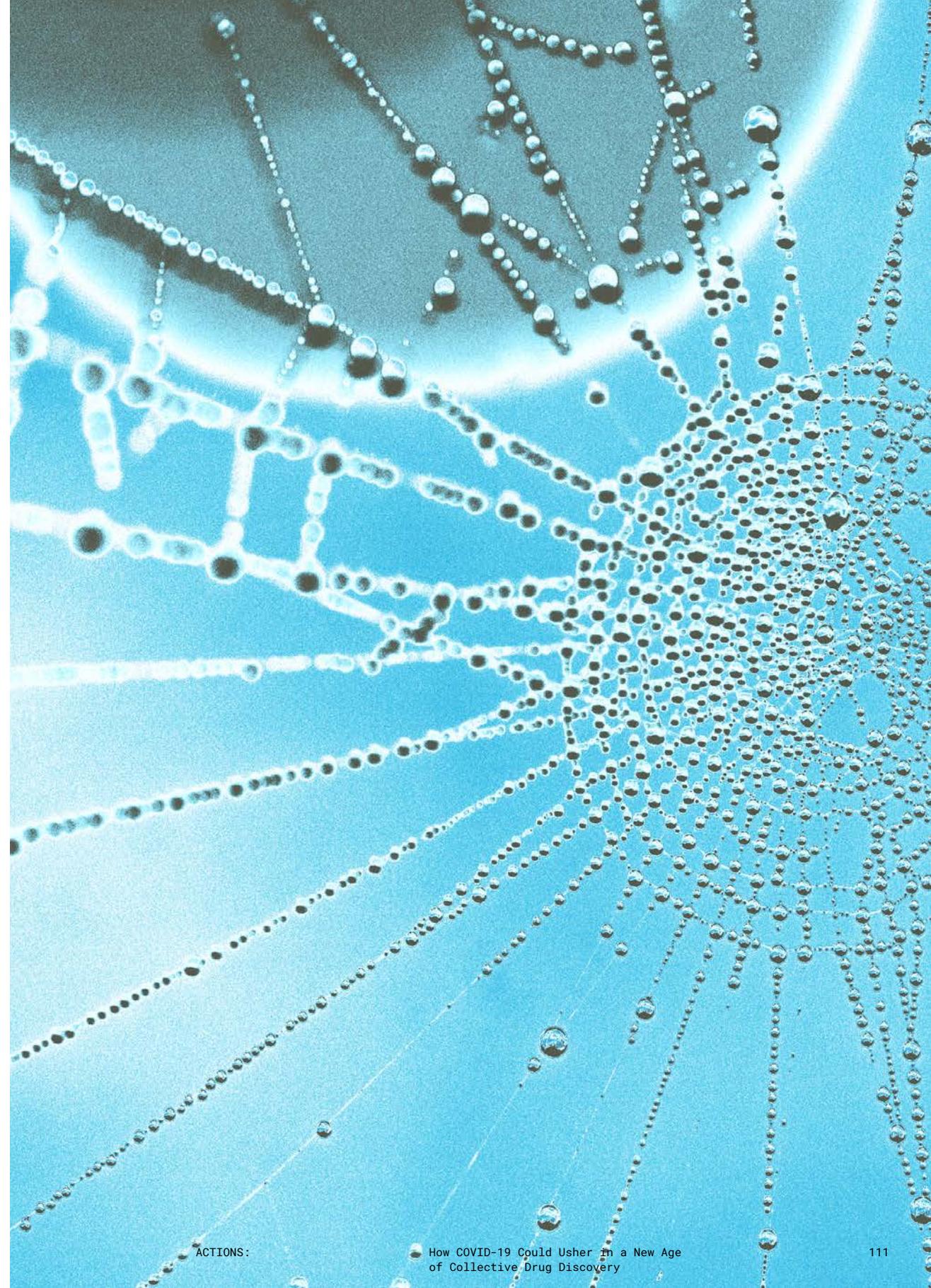
A computer simulation of one of the drug candidates that has emerged from the Moonshot project so far, showing how it sits in the COVID-19 virus structure.

Normally, ideas for how best to design such a drug would be kept as carefully guarded secrets within individual labs and companies due to their potential value. But as a result, the steady process of trial and error to reach an optimum design can take years to come to fruition.

However, given the scale of the global emergency, Lee felt that the scientific community may be open to collective brainstorming on a mass scale. “Big Pharma usually wouldn’t necessarily do this but time is of the essence here,” he said. “It was a case of, ‘Let’s just rethink every drug discovery stage to see, ‘Ok, how can we go as fast as we can?’”

On March 13, he launched the COVID Moonshot, calling for chemists around the globe to come up with the most creative ideas they could think of, on their laptops at home. No design was too weird or wacky to be considered, and crucially nothing would be patented. The entire project would be done on a not-for-profit basis, meaning that any drug which makes it to market will have been created simply for the good of humanity.

It worked – within just two weeks more than 2,300 potential drug designs had been submitted. By the end of April, over 4,000 had been received from scientists around the globe.





The Road Toward Clinical Trials

With so many designs to choose from, the next step involved finding a way to whittle them down to create a shortlist of the most promising. The expertise of computational drug discovery experts at Diamond and the Weizmann Institute of Science in Rehovot, Israel, has enabled the Moonshot team to develop algorithms for predicting how quick and easy each one would be to make, and to predict how well each proposed drug might bind to the virus in practice.

The latter is an approach known as computational covalent docking and has previously been used in cancer research. “This was becoming more popular even before COVID-19, with several covalent drugs approved by the FDA in recent years,” said Nir London, professor of organic chemistry at the Weizmann Institute, and one of the Moonshot team members. “However, all of these were for oncology. A covalent drug against SARS-CoV-2 will certainly highlight covalent drug discovery as a viable option.”

This approach has whittled the submissions down to just 200. Over the past few weeks, the team has raised funding for the most promising of these – compounds which Lee has dubbed the ‘golden tickets’ – to be manufactured. This process is being partially financed by crowdfunding as well as contributions from research labs around the globe. Over the next month, each one will be put through a series of rigorous preclinical tests to make sure they are safe and to see whether they are effective at killing the virus in a test tube and in rodents.

While it is still too early to begin planning clinical trials, the Moonshot team aims to have a prospective drug candidate by the end of the summer, allowing them to reach out to potential pharmaceutical partners to test their compounds in humans.

Future Implications

If the project does succeed, some believe it could open the door to scientific crowdsourcing as a future means of generating novel medicine ideas for other diseases. Frank von Delft, professor of protein science and structural biology at the University of Oxford’s Nuffield Department of Medicine, describes it as a new form of ‘citizen science.’

“There’s a vast resource of expertise and imagination that is simply dying to be tapped into,” he says.

Others are slightly more skeptical, pointing out that the uniqueness of the current crisis has meant that many scientists were willing to contribute ideas without expecting any future compensation in return. This meant that it was easy to circumvent the traditional hurdles which prevent large-scale global collaborations from happening – namely how to decide who will profit from the final product and who will hold the intellectual property (IP) rights.

“I think it is too early to judge if this is a viable model for future drug discovery,” says London, the chemistry professor and member of the Moonshot team. “I am not sure that without the existential threat we would have seen so many contributions, and so many people and institutions willing to waive compensation and future royalties. Many scientists found themselves at home, frustrated that they don’t have a way to contribute to the fight against COVID-19, and this project gave them an opportunity. Plus many can get behind the fact that this project has no associated IP and no one will get rich off of this effort. This breaks down a lot of the typical barriers and red-tape for wider collaboration.”

However the Moonshot team believes that if they can succeed, it will at the very least send a strong statement to policy makers and the scientific community that greater efforts should be made to enable such large-scale collaborations.

“All across the scientific world we’ve seen unprecedented adoption of open-science, collaboration and collegiality during this crisis, perhaps recognizing that only a coordinated global effort could address this global challenge,” says London. “If a drug would sprout from one of these crowdsourced ideas, it would serve as a very powerful argument to consider this mode of drug discovery further in the future.” ■

David Cox is a science and health writer based in the U.K. He has a Ph.D. in neuroscience from the University of Cambridge and has written for newspapers and broadcasters worldwide including BBC News, The New York Times, and The Guardian.

