






VIEWPOINT

Lessons of COVID-19: A roadmap for post-pandemic science

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The response to the COVID-19 crisis across most research institutions mandated ceasing nonessential research activities in order to minimize the spread of the virus in our communities. With minimal notice, experiments were terminated, cell lines were frozen, mouse colonies were culled, and trainees were prevented from performing bench research. Still, despite the interruption of experimental productivity, the shutdown has proven for many PIs and trainees that doing and thinking science are not activities that are bound to the laboratory. Furthermore, the shutdowns have solidified important emerging trends and forced us to further innovate to get the most out of working remotely. We hope that some of these innovations, hard-gained in this difficult time, will persist and develop into new paradigms—lessons that will improve our science and our relationship to the climate and community beyond the current pandemic.

The labs were shuttered. We sat at home on Zoom. Many sought and found ways to help their institutional teams to do science on the pandemic that kept us home. During the following three-plus months, most of our laboratory science suffered considerably. Working from home was complicated by many factors, including sickness, stress, loneliness, loss of childcare, and unevenly shared household responsibilities. But as a collection of PIs, postdocs, and graduate students, the time away has also provided us with visions of a different future, incorporating lessons that make that future brighter than one might have expected.

Finding productivity in time away from lab

While science certainly looks different from home, many of us are benefiting from time spent in reflection and more careful processing of our data. In some cases, we have been surprised at finding just how deep the backlog of analysis had become. Without the temptation to prioritize new experiments,

some have taken the opportunity to learn new analytical pipelines via online coursework, such as R or Python tutorials, Khan Academy, or Massive Open Online Courses (MOOCs). With these expanded resources, many have found new value in existing datasets. This forced sabbatical has given us insight into how we might differently process our research workflow in the future.

With time away, some of us have had a chance not only to catch up on the reading in our field but, with no long commutes and more freedom in what we consider normal work hours, we have done the kind of broad reading that sparks innovative scientific proposals. Many of us have been able to focus on the important duty of communicating science, whether by preparing manuscripts, writing reviews, or by engaging the general public on the importance of the public health measures necessary to address the pandemic. For those whose work time merged with family/life time, we found new tools to help us prioritize, enabling maximum possible efficiency and



Illustration by Ana Catarina Silva.

productivity on a limited number of objectives within newly circumscribed work cycles.

Going forward, as research in many places slowly starts to ramp up, it seems likely that many of us have become better at prioritizing between spending time in the lab, communicating with our mentors and peers virtually, and maintaining a thriving

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scientific enterprise. If there is a lesson here, it is that time spent with data and ideas needs space to compete with the rush to set up the next experiment.

Reevaluating lab management and culture

Labs have always had tension in defining a home-work boundary, placed between extremes of invasiveness and aloofness. A tendency toward group culture may lead PIs to view individuals through the lens of the dominant personalities. Quarantine has realigned these norms. We now live intensely at-home lives, but “work hours” are less clearly defined. In quarantine, trainees’ décor and partners are in full view; in return, so are PIs’ dedicated home offices (or lack thereof) and anxious children. This forces us all to acknowledge that productivity is influenced by anxiety, deaths of loved ones, childcare, and isolation.

As PIs, we are working to be more attuned to the individual needs of trainees instead of bending toward an average or dominant style. On a daily basis, we remind ourselves that trainees may have nonobvious reasons for wanting to stay home or return to the lab. We try to minimize invasive questions but do not shy away from strong feelings. We invite discussion about what is truly important to the individual alongside their role in the lab.

The trainees among us have been encouraged, if at times surprised, to see the humanity in our PIs. Removed from the more formal setting of the professional environment, it’s clear they are equally flawed, equally capable of self-doubt, and hopefully collaborating with their trainees to adapt to a new system. Facing this common crisis as part of a team should provide all of us with a lasting appreciation of the cryptic complexities of our labs. We can aim to preserve scientific intensity while acknowledging that periods of enthusiasm and crisis are not always so visible and aligned. We can avoid the extremes of invasiveness and indifference by knowing our labs as individuals. We can bolster coping skills without demanding information or fostering dependency. We can promote a culture of trust and openness, respecting everyone’s time as being as precious as our own, taking turns, sharing credit, sharing bench space, and seeking advice. Going forward, we hope to increase our productivity, creativity, and scientific

and workplace satisfaction by expressing our preferences openly and listening to our colleagues’ concerns as avidly as we expect them to hear our own.

We can reduce global emissions and still exchange ideas

The life of a scientist in its pre-pandemic form included frequent travel to seminars and conferences worldwide. While communication of science is very important, the resulting carbon footprint has always been concerning. How can we, who exhort lawmakers to act immediately against climate change, still carry on with this lifestyle? With the spread of SARS-CoV-2 and related travel bans, this pattern came to a sudden end. Did this stop scientists from communicating and exchanging ideas? No. In fact, scientists quickly found alternatives to previous routines.

Speakers were invited for online seminars. With some thoughtful attention to human interactions, this new form of meeting had an additional advantage over the PI traveling alone: it allowed the inclusion of trainees in discussions about data and collaborations—paired lab-to-lab meetings—something that was not financially or practically possible before. Additionally, we have been able to talk to scientists all around the globe without losing days in transit. Some universities had already implemented online seminar formats even before SARS-CoV-2 ([UCSF Eco Seminar, 2020](#)), and this model is gaining traction. Other decentralized seminar series, such as the highly regarded [Global ImmunoTalks \(Global ImmunoTalks, 2020\)](#) were launched during the pandemic.

Despite these successes, we should not forget that in-person conferences are valuable vehicles, especially for younger scientists (grad students, postdocs, and junior PIs) to come into contact with the scientific community. For many, these are critical opportunities for communicating science, establishing reputations in our fields, and forming scientific collaborations and community through the very human act of passing through common space. A spontaneous discussion at a poster session, a scientific conversation over lunch, or an exchange of ideas during happy hour are not replicated by current teleconferencing platforms. But this, too, may improve, perhaps as platforms incorporating visualization tools and more flexible video chat components

can help to break down the barriers to forming meaningful small conversations in an online environment. It is even possible that these could ultimately be more efficient than real-life sessions, with presenters sending invitations to senior scientists (and vice versa) and booking virtual appointment times at posters and happy hours, to ensure that desired connections are made. With full knowledge that the next big crisis will likely be climate change, we will do well to use this opportunity to acknowledge that not all travel is strictly necessary. If we can focus our travel on quality instead of quantity, favoring fewer intensive (multi-day) visits over collecting CV line items and airline miles (and adjusting expectations for junior faculty accordingly), we should be able to increase interactions with our global community, save time, and decrease our environmental impact.

Virtual formats create opportunities for younger and different voices

Anecdotally, we may be seeing another, unexpected benefit of online seminars: increased and more active participation by young and early-career scientists, who are more willing to engage in discussion with senior researchers. Happily, it seems likely that this will continue as younger generations become increasingly comfortable with virtual lives and communication. We don’t know the source of this phenomenon as yet. Perhaps it is because courage can be better summoned in one’s own personal space, perhaps it is simply the less personal nature of virtual communication. Regardless of the source, it is unequivocally something to be encouraged and enhanced well beyond the pandemic.

We are seeing novel ways of asking questions during (and after) virtual meetings, including through social media platforms. These virtual interactions are helping to foster a greater sense of community among scientists at all career stages. Virtual seminars also have the potential to promote diversity by expanding options for parents and people with a wide range of physical abilities and medical or psychological needs, for whom travel is more complicated than just hopping on a plane. Removing cost barriers can also encourage the debut of new voices or even empower junior researchers to proactively offer to give virtual seminars

to leading research labs or departments in their field. We envision a future in which a “virtual only” qualification in response to seminar requests will become a standard option in our toolkit for disseminating science and hearing from a diverse chorus of voices.

As globalization of seminar platforms decreases barriers to lining up the best panels and increasing positive responses to invitations, we call on senior faculty to truly consider diversity in making their choices. If these novel formats are going to take hold and work for the scientific community, organizers should be given a mandate to incorporate a variety of voices, including junior faculty, trainees, and especially women and minorities who are underrepresented in or may be actively excluded from the senior ranks. These platforms should also be accountable and transparent to avoid having the same few young “superstars” at every event within a field. We believe that finding new perspectives from a broad pool of candidates will enrich everyone. Finally, we hope that global seminars will decrease barriers to communicating and collaborating with investigators in different countries. We do not yet know the COVID-related (or COVID-“justified”) impacts on future international travel and visas, but with true globalization of virtual formats, we can do our part to minimize our isolation and keep the doors open for a time when some of these limitations will be reversed.

Refining publication practices is possible and desirable

Historically, the timeline for formal communication of our work has been frustratingly long. At minimum, we expect to shepherd our manuscripts from submission to dissemination in four months, but this process often stretches to a year or longer. Prior to the pandemic a revolution was already underway in preprint servers, exemplified by *bioRxiv* and *medRxiv*, in which results could be broadcast (and tweeted, critiqued, and debated) within minutes (Sarabipour et al., 2019; Berg et al., 2016; Abdill and Blekhman, 2019). The main fear, still a matter of some debate (Abdill and Blekhman, 2019; Klein et al., 2019), is that the lack of peer review may lead to a glut of low-quality, misinformation-rich literature.

However, the explosion of COVID-19-related preprints, over 5,000 between

January and June of 2020 (bioRxiv, 2020), indicates that, in COVID, our community feels the strengths outweigh the perils. Pioneering open-access journals have even begun to offer preprint-based review as a means of accelerating publication (PLOS, 2020; eLife, 2020). In further illustration of preprint mainstreaming, the National Institutes of Health recently launched the National Library of Medicine Preprint Pilot, which will test the effects of depositing COVID-19-related preprints in PubMed Central and indexing them on PubMed. The pilot is expected to expand beyond coronavirus content as the platform is developed and made scalable.

Journals have also responded by challenging their typical timeframe, with some notable peer-reviewed manuscripts emerging within weeks of submission. A good part of this success lay with the scientists who, spurred to action by eager editors and in some cases with more control over our schedules, found time to do what we normally should and reviewed papers within a day or two of receiving them. We will need to figure out how to bring that ethos to bear beyond COVID-19; more than likely, the journals need to hear from us as a community that we prioritize quality reviewers who can accept/decline review requests immediately, agree to act quickly, and then respect the promised deadline. But the speed of some of these papers emerging also tells us that the conventional journals could equally commit to streamlining their processes around manuscript triage, editorial decisions, and immediate posting/indexing of accepted manuscripts before a timely final formatting process.

Returning to the point of our own involvement in rapidly disseminating quality studies, COVID has also given us a framework for implementing changes in peer review, which we hope will be durable. With the knowledge that new experiments were not possible within the normal revision window, reviewers were forced to consider how necessary additional data really were. Were we really protecting science by delaying a yes/no decision, or by rejecting solid but circumscribed work? This experience has built on previous attempts to limit reviewer demands and multiple resubmissions (Malhotra and Marder, 2015) and on a push to develop a reviewer compact that encourages our peers generally to approach

manuscripts with the intention of seeing good data published (Krummel et al. 2019). With support and even explicit guidance from journal editors, many of us requested additions more parsimoniously. These changes may have been spurred by the practicalities of the pandemic, but we can continue to embrace this newfound efficiency to increase the pace, digestibility, and quality of all of our work.

Collaborative human-facing infrastructure is game changing

In December 2019, the first cases of COVID-19 emerged, and a month later the World Health Organization declared a global health emergency. While the world began lockdown, clinicians and researchers immediately started to work together, tirelessly, to confront the coronavirus outbreak with an unprecedented spirit of collaboration. As scientists, we often think about the impact of our work in terms of years or even decades to come. COVID made clear that the work we do as scientists can and does matter immediately, not just to ourselves but to our world. This extends beyond COVID to all health and disease; thoughtfulness reigns supreme, but pace is important. There is strength in numbers. We learn with greater breadth and speed together.

Collaborative infrastructures and institutional networks proved critically important to launching these efforts. For instance, universities and research centers with cores or “collaboratories” dedicated to human specimens handling and performing basic research. For example, COMET at the University of California, San Francisco, and the COVID Processing Unit at the University of Pennsylvania are studies that are collecting biological samples from COVID-19 patients in order to identify immunophenotypic features for the development of effective therapeutic interventions (COMET UCSF, 2020; Mathew et al., 2020 Preprint); both profited by having central staff already assembled to process immune-based samples. At the University of Minnesota, investigators quickly formed a diagnostic testing lab, including the collaborative development of an in-house serology assay, core for processing clinical samples, and randomized controlled trials, including a test of postexposure prophylaxis (University of Minnesota, 2020). CovidCP, a platform developed at The John Hopkins University, can help with

higher-order coordination by publicizing protocols from laboratories open to collaborations (COMET UCSF, 2020). In many cases, knowledge of where existing studies are taking place supplies the missing link necessary for us to find one another and advance our research. This synergy demonstrates the power of combining improvisation and coordination possible at public institutions to support rapid research and discovery.

In this pandemic, those institutions with systems in place moved quickly, and those without could not. It is possible that the best institutions are learning in a rapid way that cores facilities are one of the most important nuclei of collaborative strength we have. Having a collaborative faculty is not just pleasant, but the best chance to solve problems rapidly. In a non-pandemic world, our institutions should place renewed emphasis on making shared resources a priority.

Science matters

Throughout this crisis, we are experiencing an increasing interest in science, with scientific findings being discussed in the public press and scientists becoming prominent figures. Many scientists are suddenly ambassadors for scientific news, knowledge, and practice, serving as valuable sources for their friends, families, and the general

public. Some of us encountered loved ones or even distant acquaintances who sought our opinions and realized that the most important role of an “expert” is not just to be knowledgeable but to help disseminate that knowledge, to digest and distill complex findings, and to aid in interpreting shallow or conflicting accounts in news media and social media. Scientists who excel at this are rapidly becoming household names.

Going forward, it is very important that we as a scientific community serve as careful stewards and do not claim unearned expertise. On the contrary, offering to go to the literature in search of answers can model how we live our values! We need to be thoughtful about this current spike in scientific interest and use this opportunity to improve scientific communication and transparency as a means to improving our society. Despite many of us being hamstrung by being shut out of our labs, there remains an unmistakable sense that society needs science.

We should be especially mindful to promote all science; to acknowledge the important work of coronavirus researchers, but also to remind lawmakers, donors, and voters of the long-term benefits of a diverse portfolio of basic and biomedical research. Discoveries that we make through an increased investment across many fields may ultimately provide a roadmap or shortcut in

our next crisis and improve the health and resiliency of our society.

If we are smart, we will embrace this moment and provide solid science and principles that others can follow. As our labs reopen, we can incorporate some of the positive lessons of this experience into our everyday and our science lives.

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