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Q&A

Public Misinformation and Science Communication in Times of Public Health Crises

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History is filled with lessons of civilizations collapsing after their citizens failed to perceive the problems developing around them or, if they did, then failing to solve the ones that would eventually cause their demise. In early 2022, almost 2 years into a pandemic, we are still coming to terms with how we ended up in the present situation: in the United States alone, over 950 000 total deaths, reaching over 1 million new cases per day, and unprecedented levels of hospitalizations that are breaking an already fragile healthcare system. It certainly felt like our way of life was collapsing right in front of our eyes, and we cannot help but think that surely this must have been preventable. After all, scientists were able to develop, test, and get highly effective vaccines approved at a record pace, but when it came to public acceptance and adoption, things were not so stellar. From the beginning, confusion regarding the transmissibility and severity of the virus led to widespread challenges to mask mandates and social distancing policies. Dangerously, the degree of widespread misinformation has led to various off-target drugs, such as ivermectin, and common household items, such as bleach, being championed as COVID-19 treatments without any scientific evidence. This problem persists as vaccine adoption across the population continues to lag due to a lack of trust in government and scientific institutions. The overall issue became even more complicated with the emergence of bad actors who tried to capitalize on this situation by spreading misinformation and undermining science for political, financial, or promotional reasons. Nevertheless, it is important to understand how the scientific community contributed to these problems and what we can learn that may help shape our current and future responses to similar threats to our society, including perhaps the greatest of all, public misinformation. Developing strategies to tackle this issue has led some, like Dr. John Holdren, the former science advisor to President Obama, to call on every scientist to become a trained communicator in an army of ambassadors for the United States. But this is not as easy as it sounds, with some, like Dr. Holden Thorp, the Editor-in-Chief of *Science*, questioning this approach. Thorp instead proposed improving the partnership between researchers and public communicators, so each can draw on their own expertise and in-depth training.

Altogether, questions can be raised about the responsibilities of scientists in sharing scientific information, not only with their peers but also with the public, as well as their role in combatting the spread of misinformation online. To explore this concept further and to acquire their perspectives on the evolving role of scientists in the 21st century, we invited a group of scientists, physicians, and journalists who are also leaders in science communication to answer key questions on this topic.

What limitations has the pandemic exposed in the ways that science is communicated today?

Holden Thorp: While scientists certainly could have done a better job communicating research findings during the pandemic, it was an uphill battle because of the political conflict and social media algorithms. Science becomes collateral damage when it becomes of intense public interest (Naomi Oreskes has called

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this "impact science"). Once one side decides to support the scientific consensus, it is a given that the other side is going to oppose it. There's not much scientists can do about this—a smoother, more accessible presentation is not going to get the opposing side on board. Further, the algorithms of the social media platforms, are designed to amplify misinformation that satisfies motivated reasoning, because this leads to more engagement. So, authoritative information has a hard time getting through. Scientists could have done more with phrasing and coordinating messages, but it wouldn't have been enough to get through these 2 barriers.

Richard J. Tofel: The frontiers of science are often (usually?) marked by complexity and uncertainty; not surprisingly, this has proven especially to be the case during a pandemic involving a previously unknown pathogen. But too much of the communication about this emerging science has sought to oversimplify what is complex and downplay what is uncertain.

This approach may have attractions in the short term, but it saps public trust when what is actually driven by evolving knowledge (e.g., asymptomatic spread) or changes in circumstance (e.g., a new variant) comes to be seen as "flip-flopping" in guidance.

Beyond that, in communicating with the broad public, too little attention has been paid to the necessity of communicating in language they understand—for instance, not acknowledging how limited is most people's understanding of statistics and recognizing that scientific terms such as "airborne" with respect to a virus may not share the colloquial meaning of the same word.

Joseph S. Ross: To my mind, the pandemic has illustrated the challenge of effective scientific communication, both for policymakers and the media as well as for scientists. Science is complicated and iterative, and rarely conclusive. The biggest change to come about from the pandemic is that the scientific community had (mostly) never before thought it had a responsibility to communicate with the public. For sure, there were medical and science journalists who paid attention to major conferences and journal publications and communicated these findings to the public. But during the pandemic, the general public was suddenly paying close attention to the scientific community's research, publications, and communications. We have been communicating via medical journals, preprints, and even blogs and Twitter for years. Now the public was following along in real time as data were being analyzed and discussed. And it was not just medical and science journalists who were accustomed to how science is typically communicated, but all types of journalists whose beat was affected by the pandemic and public health measures. My sense is that it took some time for everyone to get comfortable with how much uncertainty there actually is in science—most estimates are of a range, most predictions are based on probability. Early communications through the media or from public policymakers were unnecessarily authoritative: this drug works, this policy is not needed. Now more nuance is being communicated and the uncertainty of the evidence underlying an article or a policy is made clear.

Apoorva Mandavilli: From the perspective of a reporter, one big lesson from the pandemic is that scientists—and to some extent, science reporters—struggle to communicate the iterative and incremental nature of research, and the arguments and disagreements that are an integral and important part of the scientific process.

This mattered less before the pandemic because scientists rarely engaged directly with the public. Outside of educational settings, most concepts were communicated to the public by reporters or by other science communicators. But the information accessible to reporters was itself heavily filtered at multiple steps—by academic institutions, research journals, and by the scientists themselves—and simplified into a digestible form that often belied its complex context.

This system served no one well, least of all the general public, who were spoon-fed a diet of preordained stories. By leading to a profusion of stories all purporting to "prove" some claim or the other, they led to a false sense among the public that the science was definitive and settled.

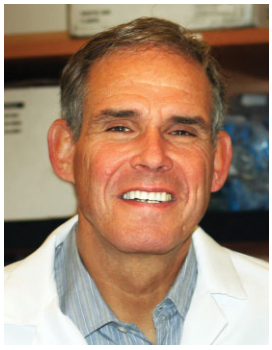
The pandemic changed much of that, some of it for the better. It gave the public a front-row seat to the evolving and iterative nature of scientific research and shone a spotlight on the intense disagreements that can color any field.

It also fast-tracked the acceptance of preprints among life scientists. While physicists and mathematicians have embraced preprints for more than 30 years,

biologists have fretted that preprints would allow their competitors to steal their ideas or that the public would misunderstand crucial medical concepts.

This new way of doing things was not without its problems and no doubt resulted in some dubious papers getting more attention than they should. But that was not unheard of even with peer-reviewed publications. Overall, by bypassing the many levels of gatekeeping, the approach democratized and accelerated the flow of information.

But the greatest advantage of a faster flow of information is that it allows the public to see science in its raw, unpolished form, giving them a much clearer sense of the human and fallible nature of scientific enterprise. The honesty of this portrayal may have painful consequences in the short term, but it is the only way in the long term to build a relationship of trust.



Eric Topol: There is an aggressive antiscience, antivaxx, antimask force that is organized, mediated through both television and across all social media channels, spreading unmitigated mis- and disinformation, that has had a profound impact and lack of any counter from the United States.

How do you balance between delivering incremental information to the public from small studies, which potentially could create confusion, and waiting for the definitive ones?

Holden Thorp: I don't think we need to overthink this. Let's get information out there accurately when we can. The larger problems are not affected by this one way or another.

Richard J. Tofel: Both scientists and journalists need to be more modest in communicating the results of single studies of almost any sort. One clear analogy is to public opinion polls: as anyone with a command of statistics knows, a single poll can relatively easily (perhaps 1 time in 20) be simply wrong, but an average of rigorous polls almost always is reflective of population views. That analogy isn't at all an argument against publishing individual studies, but it is a major caution in interpretation, especially if a single study truly breaks new ground or is based on a small sample. The solution isn't silence, but it is modesty.

Joseph S. Ross: Individual studies are rarely definitive —that's simply not how medical and public health research advances knowledge. For sure, any single large, randomized, double-blind, placebo-control clinical trial provides more "definitive" evidence than a smaller trial or than an observational study. But all studies are intended to advance the evidence and should be considered as a constellation of information that in aggregate improves our general certainty about what is best and safest for patients and the public. There is always the risk of overreacting to any single research study, but as a field we are better off when each additional piece of evidence is promptly communicated to the clinical and scientific community. Three small trials, all with consistent effect sizes, may be as definitive as one large trial. Ensuring this information is made available rapidly and responsibly allows professional guideline developers and clinical experts to iteratively refine their recommendations over time.

Apoorva Mandavilli: There is no easy or generic answer to this question. The solution depends on the type of information, its importance, and its urgency.

There is a broad overlap between what scientists may consider incremental and what is inessential for the public to know. But it is not always an exact match. The findings from a paper may be statistically significant and yet have no real relevance in the real world. Conversely, it would be a mistake to think that all incremental findings are unimportant.

Often what scientists consider too preliminary to share can have weighty consequences for the average person. For example, there was enormous pressure on reporters not to write about potential side effects of the vaccine such as myocarditis until the science was fully settled. The potential harm to the readers was obvious—that misplaced worries might prevent some from getting the vaccine and leave them vulnerable to the virus.

The solution in these cases is not to make the paternalistic decision to shield the public from the information until scientists have all agreed that it is ready to be shared. Instead, scientists and reporters should lay out the potential risk, put it into context, and explain that knowledge of the situation is still evolving. Clearly detailing what is not yet known and what still needs clarifying is sometimes just as important, if not more so, than explaining what is known.

A good reporter will signal to the reader that something is preliminary—by using that very word, for example, or by mentioning that the sample size is too small to draw definitive conclusions, or that the study left some blanks that still need to be filled in before the finding is actionable.

Most studies contain this information, and honest researchers will not shy away from pointing them out to reporters. But even if they do not, independent commenters are crucial for pointing out the limitations and caveats.

Eric Topol: It would be great to always wait for definitive studies, but sometimes "good things come in small

packages" that provide helpful insights and deserve raising awareness.

What responsibilities, if any, do scientists have when it comes to communicating their science to the public? And why?

Holden Thorp: There are things that can be done better. Scientists need to emphasize that science is an honorably self-correcting process, so that any statements given are a snapshot in time. This is a tough challenge because the way science is taught in school, it comes as a textbook that seems fixed. Science is not a set of facts—it is a process. We have a lot of work to do to get the outside world to understand that. The second thing is to be very careful not to get carried away with overstating what we can do. Masks help but do not prevent all infections. If we had said "masks help" instead of "masks work," it would have made it harder to undermine masks.

Richard J. Tofel: Scientists need to "follow the science" in sharing with public officials and the general public what they are learning, and what actions that suggests, especially in matters of pervasive public concern, such as a pandemic. At the same time, scientists need to recognize that science, and even medical concerns generally, are often not the only factors that need to be weighed in decision-making. In a democracy, that responsibility —considering such factors as the economy, equity, educational imperatives, national security, even national morale—is reserved to our elected leaders.

This means that public officials, and also the people they represent, are entitled to the best scientific advice, and neither should just be told what they want to hear. But it also means that on decisions that go beyond the scientific, such as whether and to what extent schools should be in-person, scientists need to recognize that the last word is not appropriately theirs.

Joseph S. Ross: Scientists have the responsibility of communicating clearly with the public, to avoid having their communication of their findings from being misunderstood or misinterpreted. By that I mean, when presenting the research, put the findings into context of prior studies and give realistic statements of the study's limitations. Scientists should be comfortable noting that there are potential criticisms of any study and be willing to engage those criticisms constructively. And scientists should prompt other, independent scientists to offer their perspective on one's work. If it's of public interest, make sure the public hears from multiple points of view.

Apoorva Mandavilli: Without question, scientists owe it to the public to communicate their science—for a myriad of reasons.

From a purely financial perspective, most scientific research in the United States is funded by federal dollars disbursed by the National institutes of Health. As such, the public has a right to know what came of the work they funded.

But beyond this more prosaic consideration, scientists have an ethical obligation to talk about their research, particularly when it impinges on people's lives in some significant way.

In my opinion, if scientists want to fulfil their obligations to communicate their work to the public, the single best thing they can do is make time to talk to reporters, honestly and clearly, without prejudging the value of the information to the general public.

Spending a half hour talking to one reporter at a widely read publication can reach hundreds of thousands or even millions of readers at once. This is a valuable public service, and one whose importance cannot be overstated.

Much as scientists would like to control how and when their work is presented to the public, it is in the public's best interest that that job falls to reporters who have no inherent agenda or bias of their own. That system may not be perfect, and reporters do get things wrong on occasion. But as we have seen during this pandemic, it is much, much worse when scientists don't acknowledge the limits of their knowledge or talk about science as if it is a monolithic, unchanging truth.

Eric Topol: Ideally, all scientists would help weigh in with evidence-based information and insights to help the public counter those with malicious or ill-intent. Most scientists are still reluctant to get involved, keep their "head down," but their inputs would be of enormous value to promote understanding and add to constructive exchange of ideas within the science community and to the public.

Do scientists have a responsibility in discrediting misinformation that is spreading online? If yes, why and how? If no, why not?

Holden Thorp: It's a great thing to try to do, but it's an uphill battle given how powerful the algorithms at the social media companies are.

Richard J. Tofel: The responsibility for rebutting (and in some especially dangerous cases, quashing) misinformation must be a shared one, implicating the platforms through which it often metastasizes, the press, the government, and others, including the scientific community. But the principal role of scientists in this ecosystem is to provide accurate information, not to police its use or misuse; scientists have no special skill in that policing, while others do (or should).

That said, we were reminded especially in 2020 (and occasionally more recently) of the special

responsibility scientists have when the misinformation is coming from official sources, even elected officials. In such cases, scientists, particularly those in public service, have a moral and professional duty not to facilitate such misinformation and to check it where they can.

Joseph S. Ross: This is a very tricky question. I am sure that any scientist feels it is their responsibility to correct the public record and discredit misinformation spreading online about their area of expertise. But taking on this responsibility imposes a substantial burden, especially for scientists working on more controversial topics, such as vaccine safety, climate change, gun control, and abortion. These issues have become so politically polarized, and such a target for misinformation campaigns, that it is unfair to assign scientists the responsibility of discrediting these efforts. In fact, if these scientists took on the responsibility, it would very likely impede their ability and capacity to conduct any further scientific study. Further, these campaigns are not honest efforts to debate and discuss scientific findings, so no scientist would ever be effective at mitigating the misinformation spreading online. Instead, discrediting these misinformation campaigns is the responsibility of the online platforms that enable them in the first place. These companies are in a better position to monitor and ensure that truthful communications are prioritized, not disinformation.

Apoorva Mandavilli: The answer to this question is not much different than the previous one. It is a fallacy that science is independent of politics or that scientists should stay out of the fray.

Scientists must speak up, often and clearly, when they see misinformation. They can do so via reporters, on social media, or directly by giving lectures to the public.

Misinformation spreads for many reasons, and it thrives in the absence of good information. One reason it takes root so strongly is that it offers simple, clear messages that people can grasp—unlike the often more nuanced and complicated scientific truth. But instead of being discouraged by the ease with which misinformation spreads, scientists can learn to give the correct ideas, ideally stated as simply and clearly as the myths are.

On an individual level, all scientists can contribute to more honest discussion of concepts by not hyping their own work, giving credit to competitors or predecessors when it is due, and being honest about the limitations of their findings. Given the number of sources of misinformation, we need every scientist who is able to do their best to disseminate an accurate picture.

We know that people are also more receptive to ideas when they come from trusted sources. And the nature of those sources can vary greatly within a population. The more diverse the researchers who are out front discussing science in front of the public, the more likely the group is to include scientists the public can relate to. Diverse groups of scientists may also have more creative ideas on how to reach the public and engender their trust.

Eric Topol: Absolutely, yes. Unfortunately, it has been well documented that misinformation spreads at a much higher velocity and more broadly than truth and facts. Our best shot at preventing its harm is all working together.

How can we improve the public's trust in science?

Holden Thorp: A lot of possibilities, but 2 things stand out. One is to try to find intermediaries that have large platforms that can advocate for science. The antiscience crowd—Rogan, Bongino, Shapiro, Carlson—have huge followings, much bigger than mainstream media and certainly any scientific outlet, even *Science*. That's hard to compete with. We need our own figures who have just as large a platform to advocate for us. Second, we need a more locally focused strategy. People respond to how things impact them. Climate change impacts Miami differently than Iowa. We shouldn't be using the same strategy for both—we need people on the ground in both places with customized messages.

Richard J. Tofel: See answer to Question 1. After accuracy, trust should be the paramount goal in communicating about science, especially in a public health emergency.

Joseph S. Ross: Trust is fragile and, once lost, is challenging to earn back. There are key principles that should be prioritized to improve trust, including transparency, honesty, and accountability. With respect to transparency, scientists should be forthright about their research, including its planning and conduct. They should publicly post trial protocols and prespecify study endpoints. They should report all research results in a timely and publicly accessible way. They should share data collection instruments, statistical code, and even research data at the end of the study with other investigator teams. With respect to honesty, scientists should communicate truthfully and clearly about all decisions made during a study, including cautiously summarizing the advances made through the study, as well as the limitations of the work. Finally, with respect to accountability, scientists should be open to criticism, admit when errors are made, follow through on commitments made, and publicly explain when and how circumstances have led to a change to the study.

Apoorva Mandavilli: Honesty, honesty, honesty.

It is difficult to overstate the importance of candor in creating trust. One of the biggest problems during

this pandemic is that people were lied to, repeatedly, ostensibly for their own good.

They were told that masks are unnecessary, simply because public health leaders were afraid that a run on surgical masks would leave healthcare workers unprotected. They were told that vaccinated people cannot be infected or spread the virus to anyone else, even though respiratory virus experts all knew otherwise, because health officials wanted to give people an incentive to get vaccinated. They were told that all Covid vaccines are equally good when it was abundantly clear later that while they were all good, they were far from equal.

This paternalistic approach to communicating with the public has backfired over and over—and yet it continues to be the one many experts employ.

Think how much better it would have been if the experts had been honest—if they had said, "We *think* this might be true, but we could be wrong" or "This is all we know, but we will tell you more as soon as we find out."

About a year ago, I was scolded by many scientists for reporting that while small gatherings did contribute to cases, they were not driving the surge as political leaders claimed—that nursing homes, restaurants, and other large gatherings were still the primary contributors. It is my job as a reporter to hold leaders accountable for their falsehoods, not to obfuscate the truth so that people will do the right thing.

Every reporter I know has examples like this. The truth will come out, and when it does, is it better for the public to be unsurprised because they were given early notice of it, or they feel misled and lied to and look elsewhere for their information?

Scientists may be driven by a desire to shield the public from misinformation and to motivate them to take the right actions. But by pretending that the science they know is on more solid ground than it actually is, they are in fact driving people right into the hands of those who spread misinformation.

Eric Topol: By frequent and highly understandable, interactive, bidirectional communication, full engagement with the public, through as many channels as possible.

Do you use social media to communicate or consume scientific material? If yes, which platforms, how and why? If no, why not?

Holden Thorp: Yes. Mostly Twitter. The algorithm is still influential, but not nearly as much as Facebook. I don't try to spread my own scientific information on Facebook, although *Science* has many followers there, and we post a lot of our stuff. *Science* has a comparable number of followers to Dan Bongino on Facebook (roughly 5 million for each), but Bongino's posts beat ours on engagement by many orders of magnitude because they're much better suited to creating conflict that is amplified by Facebook's algorithm.

Richard J. Tofel: First, it should be noted that I am not a scientist. But yes, I do find Twitter (and to a much lesser extent LinkedIn) a very useful way to become aware of and sometimes to amplify scientific information, as it is for news of all kinds. To be sure, it's also important to carefully curate one's feed as the first defense in separating wheat from chaff.

I confine my use of Facebook to personal and family matters. It seems the least I can do in responding to what I see as the company's lack of concern for democratic norms and justice more generally.

Joseph S. Ross: I use social media to both communicate and consume scientific material. I find Twitter to be among the most engaging and instructive social media platforms, allowing me to stay abreast of studies being discussed by peers, some of which are published in high-profile journals, but others of which I might have otherwise missed. To me, the key to effective social media communication is to be open minded and constructive. There is no reason to be rude or demeaning. We should all bring humility to our Twitter feeds, as we can all stand to learn from one another.

Apoorva Mandavilli: I primarily use Twitter. Even though I've had a Twitter account since 2008, I was not all that active before the pandemic. But once the pandemic began, it was clear that the kinds of scientific conversations that happened at niche conferences were (and still are) happening on Twitter. It became a place for me to eavesdrop on these conversations and spot trends early. I can also look at what scientists are saying about a particular preprint or paper, and I can see points of disagreement among scientific groups.

Twitter has also become the place to engage with the public—although that has not always been pleasant. When people spout misinformation, I've seen it as a signal that something is being widely misunderstood, and perhaps deserves an article to dispel the myths. But sometimes the noise can drown out useful information.

Eric Topol: Yes, I put considerable effort to communication through Twitter, posting new data and analyses. I think Twitter has liabilities with toxic responses and organized mob attacks, which can be ad hominem, and Twitter [the company] does essentially nothing to help deal with these. But the net benefit of transmitting solid information at scale, and the exchange of ideas from reliable sources and people, is quite worthwhile.

What advice can you share with scientists who are interested in improving the way that science is communicated, including those who may not already be active on social media?

Holden Thorp: Most important, demand respect for what you are doing. The world of science puts far too much emphasis on the actual research findings and not on all of the people who make it useful either in applying or communicating them. That is hurting us. Outstanding science communicators are just as important as the researchers. Let's celebrate and thank them!

Richard J. Tofel: In arguing, as I do in my previous responses, for the virtues of ambiguity, complexity, uncertainty, and modesty in communicating about science, I would urge scientists who have not already done so to consider Twitter as one vehicle for this. The Twitter thread can be a powerful way of communicating a logical, factual argument, complete with appropriate caveats and qualifications. Moreover, the replies, while often silly, can also provide important and prompt feedback about how clearly you are really communicating.

Joseph S. Ross: My only advice is to get involved. Communicating science is challenging. Some people are out there deliberately spreading misinformation. But most are engaged in good faith efforts to better understand and learn from one another. The more constructive communication there is, especially on social media, the better off we all will be.

Apoorva Mandavilli: There are many things scientists can do to improve the way they communicate science.

One easy way is to talk about your science with anyone who is willing to listen—to practice your elevator pitch or cocktail conversation. Talking to nonscientists is a great way to rid your communication of jargon, complicated words and concepts, and unnecessary caveats—to not "bury the lede" as we say in journalism.

Many academic institutions offer classes for scientists interested in improving their communication skills. Media training and courses on grant writing can also help. There are fellowships for scientists interested in communication—for example, the AAAS Media Fellowship, which places scientists in newsrooms.

If you are interested in writing, write as much as you can and whenever you can. You can reach out to your institution's media office and help write press releases. You could start a blog or contribute to an existing one. You can offer to write op-eds for mainstream publications or even just the university newspaper to begin with.

Finally, make time to talk to reporters. A good reporter will help you become a better communicator simply by asking you questions and pushing you to explain your work clearly. The more interviews you give, the better you'll become at explaining your research in a way that will make sense not just to reporters but to the public.

Eric Topol: Get involved. It's essential. Post your own studies with an explainer thread that anyone can understand. Altimetric is highly influenced by social media pickup, and it is clearly becoming another way for gauging the impact of a researcher's work. Once a scientist is engaged in communicating via social media, they will learn to be an even more effective communicator from the feedback and posts from others, no less helping the science community and public by adding facts and truths to the mix.

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