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Pandemics Call for Systems Approaches to Research and Funding

BY JENNIFER KUZMA, KHARA D. GRIEGER, CHRISTOPHER L. CUMMINGS, ZACHARY S. BROWN

National strategies must incorporate social as well as natural sciences.

Facing a pandemic such as COVID-19, attention naturally turns to developing rapid and reliable diagnostic tests, effective treatments, and vaccines. But we should not over-rely on biotechnology solutions. We must acknowledge that COVID-19 poses a broader and more systemic risk, arising from the interconnected nature of modern societies and driven by multiple interacting feedback loops among financial, food, labor, ecological, political, and social systems. Such feedbacks can exacerbate or dampen how the disease propagates, how health officials respond, and how technological solutions are adopted.

US research priorities and institutions are not structured to address global systemic risks such as COVID-19. Rather, they overemphasize biomedical and natural science research, and too often take a piecemeal approach that limits a full-picture or systems-level view. We call for systems-thinking approaches to research and funding to match the wicked problems associated with pandemic risks. These approaches are likely to require significant, if not radical, institutional rearrangements to US science and technology policy. We propose several guiding principles:

Emphasize social science research as an equal partner in pandemic response. As of early May, the federal government has failed to coordinate simple actions to save lives from COVID-19. Adequate supplies of masks, gloves, and ventilators are still unavailable in many areas that need them, largely due to political and market-based factors that require deeper understanding and correction. Also

missing is public trust in scientists and their pleas to socially distance, largely due to cognitive cultural biases (which often affiliate with political parties) and psychosocial dimensions of risk management that are not fully understood. The social, economic, and political sciences underlie the most important preventative actions that can be taken today—but are not.

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It is therefore puzzling that a majority of the rapid-response funding opportunities from federal agencies do not address these areas. One exception is the recent National Institutes of Health call for *supplemental* COVID rapid-response social-science research, which encourages principal investigators with an existing grant to add social, behavioral, or economic research to their projects. But even this approach is problematic in that social science research is seen as an "add-on" to biological research. It prevents interdisciplinary teams from working on an equal footing from the start of a project to design research approaches across social, biological, and health systems.

The COVID-19 situation also underscores the need to revamp the longer-term federal research and development portfolio to align the most pressing challenges from the outbreak. To date, the R&D portfolio has emphasized biotechnologies for medical treatments at the expense of the societal context from which these inventions arise or into which they must be placed. Consider the Department of Health and Human Services' 2018 fiscal year budget for academic R&D: out of $23 billion, only $350 million, or 1.5%, was devoted to social sciences.

To be clear, during this crisis phase of COVID-19, federal dollars should first be used for procuring and distributing personal protective equipment and ventilators, running real-time clinical trials with existing safe drugs, and providing financial assistance to those suffering from economic impacts. However, beyond these immediate needs, funding should no longer neglect the sociological, political science, and economic dimensions of these challenges. Societally positioned research can help to understand the root causes of inaction and distribution inefficiencies that cost lives, especially in early stages of novel pandemics.

For example, risk communication research can discover how public information translates (or not) into public action to socially distance, wear masks, or practice regular handwashing. Other communication research could investigate the role of social media in the spread of misinformation surrounding COVID-19. Economic studies can analyze the cost-benefit trade-offs of fiscal stimulus packages or proposals to end social distancing. Policy sciences can assess whether local private-public partnerships or top-down federal deployments are better institutional arrangements for disease testing and response, as well as illuminate policy actions that have worked during other pandemics under various national contexts.

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We understand that equal funding for the social and natural sciences may not be equitable, given the higher cost of biomedical research due to chemical reagents, expensive equipment, and regulatory trials. Instead, we propose an equal number of large-scale projects for social sciences as for biological sciences—or better yet, the same number of principal investigators coming from social and natural sciences on systems research, as described below.

Take problem-based and systems approaches. The pandemic crisis requires systems thinking and integration across the natural and social sciences. Yet current science and technology funding programs are partitioned by agency mission, and even further within disciplinary-based divisions of those agencies. These barriers need to be removed. Consider that COVID-19 is widely believed to have originated when a bat passed the novel coronavirus (possibly through another intermediate animal) to humans in an animal market in China. Although ecologists can understand the role of bats in ecosystems, and sociologists can study the role of animal markets in society, it takes collaboration with virologists, economists, and political scientists to tackle questions such as: What socioeconomic variables cause humans to interact with animal carriers of the virus? What policies might effectively and economically mitigate future human-animal interactions under the ecological conditions whereby a virus can be transmitted to humans?

Now that the disease runs rampant in humans, socioeconomic, health, and political systems are interacting to worsen the disease. Cascading feedback loops between poverty, lack of access to health care, and lower-wage jobs are coming to light, as society discovers the disturbing connection between race, social inequities, and deaths. Mitigating risks to vulnerable populations requires systems thinking about effective ways to intervene.

Systems approaches also apply to how best to innovate and deploy biotechnologies for pandemics. Risk analysis, decision sciences, and governance studies for innovation are orphan areas that fall between the cracks of federal funding agencies, as well as the worlds of practice and academic research. Society will be waiting a year or two for a COVID-19 vaccine, but it will be possible to shorten that time in the future with greater attention to R&D, regulatory and market-based subsystems, and their feedback effects. For example, how do patent policies and industrial ownership of intellectual property affect vaccine development and public trust in innovation? How can regulatory studies incorporate public values when it comes to safety, so vaccines and drugs have less chance of consumer rejection? What are the feedback loops between standards for COVID-19 tests, communication about false negatives to patients, and riskier public behavior that may amplify disease transmission?

Finally, the government needs to fund more research on nonlinear dynamics and the behavior of interacting subsystems for pandemics to find tipping points, identify policy levers to break undesirable feedback loops, and detect emergent properties. One such success story involved the

fight against polio, where system dynamic modeling revealed it was cheaper to eradicate the disease completely than to try to suppress ongoing small outbreaks. For COVID-19, scenario analysis and collaborative systems modeling could help to better anticipate future consequences of today's policies, detect potential "surprise" events, and design institutions to be more resilient to future pandemics.

Convene institutions for systemic pandemic research. The results of such systems research must be translatable for decision-making and received by policy-makers. New institutional arrangements might be required for this cross-boundary approach. We acknowledge that policy-makers have varying degrees of respect for scientific results and systems-level governance—but it will important to at least have a boundary-spanning organization for handoffs to occur. As a new sign of hope, the National Academies of Sciences, Engineering, and Medicine is beginning to convene social and behavioral scientists to serve as resources for decision-makers dealing with matters related to COVID-19. We hope this effort is successful, as it could complement federal government efforts to coordinate systems research on pandemics.

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One possibility would be for the White House Office of Science and Technology Policy (OSTP) to convene federal agencies to fund system-based research into pandemics. This could be done, for example, by OSTP's National Nanotechnology Initiative. The initiative organizes over 20 departments and independent agencies to fund nanoscale research, but most importantly, it has funded several interdisciplinary research teams and a center that supports the collaboration of natural and social scientists, as well as humanities scholars.

OSTP has coordinated a number of efforts against COVID-19, including establishing a public-private computing consortium to tackle research questions. Perhaps the office could also launch a coordinated, cross-boundary, and systems-thinking approach against COVID-19 and future pandemics. Such an effort must routinely engage diverse stakeholders, emergency responders, patients, and other public representatives in a post-normal science approach—one that includes an extended peer community beyond technocratic experts to provide input into systems models, funding strategies, and decisions. Policy-makers with budget authorities or emergency response mandates should also be involved and receptive to hear from researchers and stakeholders.

Much of this systems-based approach could be done quickly, through rapid-response funding calls. Results could begin to flow well before there is an effective COVID-19 vaccine. Giving equal deference to the natural and social sciences, and pushing for system and problem-based research, will increase chances of saving lives both now and in the next novel pandemic.

Jennifer Kuzma *is the Goodnight-NC GSK Foundation Distinguished Professor in the School of Public and International Affairs and a codirector of the Genetic Engineering and Society Center at North Carolina State University.* ***Khara D. Grieger*** *and* ***Christopher L. Cummings*** *are senior research scholars at the center; Grieger is also an assistant professor in the university's Department of Applied Ecology, and Cummings is the director of Decision Analytica, LLC.* ***Zachary S. Brown*** *is an associate professor in the Department of Agricultural and Resource Economics and a core faculty member of the center.*

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