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COVID-19 and Boundary-Crossing Collaboration

Laura G. Pedraza-Fariña

COVID-19 unleashed a perfect storm that exposed deep cracks in the foundations of our public health and scientific research infrastructures.[1] As public health budgets faced cut after cut in the past several years,[2] states found themselves ill-equipped to mount a coordinated response: scrambling to secure enough ventilators and personal protective gear, and failing to consistently test, trace, and quarantine those traveling to and from high-infection areas.[3] We now know that these shortcomings,

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[1] *See generally* Lisa Larrimore Ouellette, William Nicholson Price II, Rachel Sachs & Jacob S. Sherkow, *Innovation Institutions and COVID-19, Part II* (Jun. 29, 2022), https://ssrn.com/abstract=4149035 (last visited Dec. 30, 2022); Rachel Sachs, Lisa Larrimore Ouellette, William Nicholson Price II & Jacob S. Sherkow, *Innovation Law and COVID-19: Promoting Incentives and Access for New Healthcare Technologies* (May 28, 2021), in I. Glenn Cohen, Abbe Gluck, Katherine Kraschel & Carmel Shachar, COVID-19 and the Law: Disruption, Impact and Legacy (in press); Gianrico Farrugia & Roshelle W. Plutowski, *Innovation Lessons from the COVID-19 Pandemic*, Moyo Clin. Proc. (Jun. 6, 2020), www.mayoclinicproceedings.org/article/S0025-6196(20)30540-1/fulltext (last visited Jan. 6, 2023); Clark Asay & Stephanie Plamondon Bair, *COVID-19 and Its Impact(s) on Innovation*, 2021 Utah L. Rev. 805 (2021); Ana Santos Rutschman, *The Covid-19 Vaccine Race: Intellectual Property, Collaboration(s), Nationalism and Misinformation*, 64 Wash. U. J. L. & Pol'y 167 (2021); Ana Santos Rutschman, Vaccines as Technology (2022).

[2] David U. Himmelstein & Steffie Woolhandler, *Public Health's Falling Share of US Health Spending*, 106 Am. J. Public Health 56, 57 (2016) (showing how public health spending in the United States has consistently declined from 2001 to 2014 and predicting its continued declined); An Examination of Public Health Financing in the United States (Mar. 2013), www.norc.org/PDFs/PH%20Financing%20Report%20-%20Final.pdf (last visited Jan. 6, 2023) ("Federal expenditures for public health make up a very small proportion of federal health-related funding"); Jonathon P. Leider, Beth Resnick, David Bishai & F. Douglas Scutchfield, *How Much Do We Spend? Creating Historical Estimates of Public Health Expenditures in the United States at the Federal, State, and Local Levels*, 39 Annu. Rev. Public Health 471 (2018) (emphasizing the fragmented nature of public health spending in the United States).

[3] *See, e.g.*, Dyani Lewis, *Where Covid Contact Tracing Went Wrong*, 588 Nature 384 (2020); Megan L. Ranney, Valerie Griffeth & Ashish K. Jha, *Critical Supply Shortages – The Need for*

despite spurring heroic efforts to jerry-build solutions with limited time and tools, cost countless lives.[4]

For its part, research infrastructure in the United States and the world over, notwithstanding its many formidable successes, is increasingly fragmented by area of expertise. COVID-19 has laid bare the perils of this fragmentation. As presentations of COVID-19 continue to baffle researchers, the virus is playing a game of cat and mouse with scientific specialties: first thought to be a garden-variety respiratory virus calling for traditional interventions such as oxygenation and ventilation, new findings about its effects on blood cells and blood circulation dynamics implicated a second set of experts such as hematologists and cardiologists.[5] The virus' wide-ranging dermatological symptoms suggest that dermatologists may also have an important role to play in our understanding of COVID-19.[6] Many patients recover from COVID-19 infection only to find themselves besieged by sequelae that span medical specialties and defy scientific understanding: psychotic episodes, failing memories, and chronic fatigue point to a neurological component to the virus' march through the human body.[7] And this is only the medical treatment side of the COVID-19 puzzle: disagreements have cropped up on questions about mechanisms of viral spread, pitting aerobiologists, physicists, and computational scientists against infectious disease clinicians on whether COVID-19 is airborne.[8] The World Health Organization (WHO) itself has framed debates around the virus' mechanism of transmission as a fight between scientific specialties, with Benedetta

Ventilators and Personal Protective Equipment during the Covid-19 Pandemic, 382 N. Eng. J. Med. 641 (2020).

4 For examples of Covid-19 mediated creativity, *see, e.g.*, Clark Asay & Stephanie Plamondon Bair, *COVID-19 and Its Impact(s) on Innovation*, 2021 Utah L. Rev. 805 (2021). *See also* Pedro Oliveira & Miguel Pina e Cunha, *Centralized Decentralization, or Distributed Leadership as Paradox: The Case of the Patient Innovation's COVID-19 Portal*, 21 J. Change Mgmt. 203 (2021).

5 *See, e.g.*, Cassandra Willyard, *Coronavirus Blood-Clot Mystery Intensifies*, 581 Nature 250 (2020).

6 *See, e.g.*, G. Genovese, C. Moltrasio, E. Berti & A. V. Marzano, *Skin Manifestations Associated with COVID-19: Current Knowledge and Future Perspectives*, 237 Dermatology 1 (2021).

7 *See, e.g.*, Serena Spudic & Avindra Nath, *Nervous Systen Consequences of Covid-19*, 375 Science 267 (2022); Maxime Taquet et al., *6-Month Neurological and Psychiatric Outcomes in 236 379 Survivors of COVID-19: A Retrospective Cohort Study Using Electronic Health Records*, 8 The Lancet Psychiatry 425 (2021).

8 *Cf.* Lidia Morawska & Donald K. Milton, *It Is Time to Address Airborne Transmission of Coronavirus Disease 2019 (COVID-19)*, 71 Clin. Infec. Diseases 2311 (2020) ("Studies … have demonstrated beyond any reasonable doubt that viruses are released during exhalation, talking, and coughing in microdroplets small enough to remain aloft in air and pose a risk of exposure at distances beyond 1–2 m from an infected individual") *with* Penn Medicine Statement on The Question of Droplet or Airborne Transmission of SARS-CoV-2 (Aug. 2, 2020), www.pennmedicine.org/updates/blogs/penn-physician-blog/2020/august/airborne-droplet-debate-article (last visited Jan. 7, 2023), ("Transmission via airborne aerosols is not supported by epidemiologic evidence outside of known aerosol-generating procedures"). *See also* Dyani Lewis, *Is the Coronavirus Airborne: Experts Can't Agree*, 580 Nature 175 (2020); Editorial, *Covid-19 Transmission-Up in the Air*, Lancet Respiratory Medicine (Oct. 29, 2020).

Allegranzi, the WHO technical lead for the task force on infection control, questioning "why … these theories [of aerosolized viruses are] coming mainly from engineers, aerobiologists, and so on, whereas the majority of the clinical, infectious-disease, epidemiology, public-health, and infection-prevention and control people do not think exactly the same."[9]

In short, COVID-19 is one of those boundary-crossing problems whose comprehensive understanding and solution requires the assembly of teams that cut across specialties. And yet our innovation ecosystem – and our funding structures – remain stubbornly organized around disciplinary lines. This tug-of-war between specialization and boundary-crossing gives rise to one of the thorniest innovation policy challenges of our times: how do we build cohesive innovation communities that nonetheless are willing and ready to cross boundaries and collaborate with outsiders? Sociologists of science who have studied the problem of interdisciplinary collaboration understand it as somewhat of a Goldilocks dilemma: getting innovation policy right requires just enough trust and cohesion and just enough cognitive diversity to generate boundary-crossing teams that can work well together.[10]

As much as COVID-19 illustrates the shortcomings of our siloed medical and scientific professions, it also represents an opportunity to rethink and reorganize scientific research infrastructure. COVID-19 has become a scientific "nucleating event" of sorts: forcing researchers from many specialties into fragile but promising forms of collaboration around a shared – and pressing – problem, and giving rise to multiple infrastructures to facilitate such collaboration. This chapter argues that forging sustainable cross-cutting collaborations will require ongoing policy action along three axes: (1) building information-sharing infrastructure; (2) creating cross-disciplinary teams; and (3) countering anti-innovation norms. The chapter proceeds as follows: Section 1 summarizes current research from sociology and history of science on the interplay between specialization and intellectual migration in scientific and technological innovation. Section 2 compares two different initiatives, Accelerating COVID-19 Therapeutic Interventions and Vaccine (ACTIV) and Operation Warp Speed (OWS), as case studies to help develop and illustrate my three policy recommendations for boundary-crossing innovation in pandemic preparedness. Section 3 summarizes likely hurdles to assembling and funding cross-disciplinary teams, together with examples of prior successful initiatives that can serve as blueprints for future funding efforts. Section 4 concludes.

[9] Dyani Lewis, *Mounting Evidence Suggests Coronavirus Is Airborne – but Health Advice Has Not Caught Up*, Nature (Jul. 8, 2020), www.nature.com/articles/d41586-020-02058-1 (last visited Jan. 7, 2023). *See also* Nick Wilson et al., *Airborne Transmission of Covid-19* (Aug. 20, 2020), www.bmj.com/content/370/bmj.m3206 (last visited Jan. 7, 2023),

[10] *See* Stephanie Plamondon Bair & Laura Pedraza-Fariña, *Anti-Innovation Norms*, 112 Nw. U. L. Rev. 1069 (2018).

1 THE PERILS OF OUR SPECIALIZED INNOVATION ECOSYSTEM

Specialization is an important, even indispensable, component of scientific and technological innovation. At its most basic level, specialization allows for the efficient management of an ever-expanding reservoir of scientific and technical knowledge, knowledge that can be filtered through the specialization "sieve" to create more easily categorizable units of knowledge. Scientific disciplines and subdisciplines function as a sieve by developing both research priorities that guide their members in choosing *what* problems to focus on out in the real world, and research tools and methodologies that govern *how* community members study those real-world problems.[11] Sociologists and historians who study the evolution of science, technology, and medicine often liken scientific specialization to the process of community-building. Forget the image of the genius scientist working alone in a laboratory – at its core, scientific work is a communal enterprise. Scientists work in communities that are held together by a set of tacitly agreed-upon research questions, methodologies, and mechanisms for evaluating what constitutes "good work" within that community.[12] It turns out that analyzing what scientists do from the perspective of what scientists *who are members of a particular scientific community* do is quite helpful to understand the evolution of innovations in science, technology, and medicine. Community in science – as in any other area in life – has incredible upsides: it generates a shared set of background assumptions (what sociologists call background "social norms") that, in turn, engender trust among its members. Such community norms, however, also have powerful downsides for innovation.

A crucial downside of allowing innovation to proceed in relatively isolated scientific and medical communities is that real-world problems do not come so neatly packaged. To the contrary, society's most pressing problems often require solutions that combine insights from diverse scientific specialties. For example, many of the twentieth century's groundbreaking scientific discoveries, such as the physical structure of our genetic material[13] or the existence of Big Bang radiation,[14] emerged out of the combination of insights from multiple scientific specialties.

[11] *See, e.g.*, Laura Pedraza-Fariña, *Patent Law and the Sociology of Innovation*, 2013 WISC. L. REV. 815, at 838–843 (2013).

[12] *See, e.g.*, *supra* note 10, at 1095.

[13] The discovery of physical structure of our genetic material, which heralded the birth of molecular biology, is widely credited to the interaction between biologists, physicists, chemists, and X-ray crystallographers. It was the unique combination of the technical skills of X-ray crystallographers and structural organic chemists with the theoretical insights of a new group of geneticists who grasped the deep implications for biology of understanding the physical structure of DNA, that made such a momentous discovery possible. JOSEPH ROUSE, KNOWLEDGE AND POWER: TOWARD A POLITICAL PHILOSOPHY OF SCIENCE 89 (1987).

[14] Evidence for the Big Bang theory of the universe, in the form of radio frequency radiation emanating from the center of the galaxy, similarly required the application of techniques developed in radio engineering to problems in astronomy. Woodruff T. Sullivan III, *Karl*

Those community norms that are so helpful in segmenting and organizing knowledge, however, fall short when innovation requires teams with diverse expertise. In their most pernicious forms, the same community norms that build trust and cohesion among community members in fact *discourage* collaboration across specialties by sowing distrust toward the research questions or methods of other disciplines. In prior work with coauthor Stephanie Bair, we have termed these counterproductive social forces "anti-innovation" norms and argued that a crucial goal of any innovation policy should be to identify and mitigate their negative impact.[15]

Anti-innovation norms can have a devastating effect on breakthrough innovation. If there is one insight that has emerged from years of joint studies in history, sociology, organizational economics, psychology, and law it is that breakthrough innovation requires not only trust but also cognitive diversity.[16] Trust provides the social glue and shared language that allow scientists to get to work on a set of common goals. But diversity, in both thought styles and methodologies, is a second indispensable ingredient. Put differently, many breakthrough discoveries emerge through the recombination of ideas, methodologies, and ways of framing problems from two or more distant disciplines. Trust and diversity, however, are forces that often pull in opposite directions. This is because trust tends to emerge from sameness – scientists tend to "trust" research and researchers who adhere to the background research priorities and methodologies of their chosen scientific community. Getting innovation policy right, therefore, is somewhat of a Goldilocks dilemma: too much specialization, too much cohesion, deprives communities of fresh ways of looking at problems and novel methodologies; on the other hand, simply throwing together teams of scientists from widely divergent backgrounds can create cacophony rather than innovation. We need just enough trust and cohesion and just enough cognitive diversity to generate teams that work well together.

Jansky and the Discovery of Extraterrestrial Radio Waves, in THE EARLY YEARS OF RADIO ASTRONOMY 3, 13 (W. T. Sullivan III ed., 1984).

[15] Bair & Pedraza-Fariña, *supra* note 10.

[16] *See, e.g.*, Stefan Wuyts, Massimo G. Colombo, Shantanu Dutta & Bart Nooteboom, *Empirical Tests of Optimal Cognitive Distance*, 58 J. ECON. BEH. & ORG. 277 (2005) ("The hypothesis is that in interfirm relationships optimal learning entails a trade-off between the advantage of increased cognitive distance for a higher novelty value of a partner's knowledge, and the disadvantage of less mutual understanding"); Bart Nooteboom et al., *Optimal Cognitive Distance and Absorptive Capacity*, 36 RESEARCH POLICY 1016, 1017 (2007) ("The challenge then is to find partners at sufficient cognitive distance to tell something new, but not so distant as to preclude mutual understanding"); Mathijs de Vaan, David Stark & Balazs Vedres, *Game Changer: The Topology of Creativity*, 120 AM. J. SOCIOL 1144 (2015); Laura Pedraza-Fariña & Ryan Whalen, *A Network Theory of Patentability*, 87 U. CHI. L. REV. 109 (2020) (developing a network measure of patent non-obviousness based on technological distance); Teresa M. Amabile, *The Social Psychology of Creativity: A Componential Conceptualization*, 45 J. PERS. SOC. PSYCHOL. 357, 365 (1985) ("Individuals who … see relations between apparently diverse bits of information, may be more likely to produce creative works and responses").

For example, the discovery of the physical structure of DNA benefitted from an unusual environment in which both trust and diversity coexisted in a fragile equilibrium. In the context of Nazi Germany, when many scientists were not permitted to attend official seminars, Max Dellbrück organized a "little private club" at his mother's house where theoretical physicists and biologists (two groups that did not routinely interact with each other) came together. As Dëllbruck puts it, "discussions we had at that time have had a remarkable long-range effect, an effect which astonished us all."[17] Scholars have hypothesized that the cohesion among these "Dellbrück club" scientists, catalyzed by their Nazi opposition, allowed for fruitful communication to take place across disciplinary boundaries.[18] Indeed, recent empirical network analyses have identified one particular network configuration – the "structural fold" – as essential for generating creative, high-impact ideas.[19] Structural folds are characterized by "cognitive distance" and "intercohesion." Cognitive distance stands as a network measure for diversity of ideas: the more cognitive distance a relevant group enjoys, the more diverse the knowledge sources that are available to the group.[20] Intercohesion refers to the area of overlap between two or more cognitively distant groups. Group members in this overlap area belong to more than one cohesive group; as a result, they can facilitate the emergence of social trust between cognitively distant group members.[21]

2 BUILDING INFORMATION-SHARING INFRASTRUCTURE

Sometimes the hurdles to creative information recombination are surprisingly simple. Information can be "sticky" and remain trapped within particular scientific communities despite it being ostensibly available to the public. It may appear surprising that lack of access to relevant information is still an important hurdle in our modern internet-dominated era. In reality, while the internet offers access to a vast amount of information, this vastness creates a second-order problem: an overabundance of information and a filtering–sorting–prioritizing problem.[22] All things being equal, communities will prioritize reading information featured in their own specialty-specific journals and presented at their society's meetings or trade shows. Having meaningful access to information requires investment in physical and

[17] Pedraza-Fariña, *Sociology of Innovation*, *supra* note 11.

[18] *See, e.g.*, Philipp R. Sloan, *Biophysics in Berlin: The Dellbrück Club*, *in* Creating a Physical Biology: The Three-Man Paper and Early Molecular Biology (Phillip R. Sloan & Brandon Fogel eds., 2011) (explaining how the Dellbruck club brought together unusual scientific disciplines, including genetics, biochemistry, and physics).

[19] *See, e.g.*, Balázs Vedres & David Stark, *Structural Folds: Generative Disruption in Overlapping Groups*, 115 Am. J. Sociol. 1150 (2010); de Vaan, Stark & Vedres, *supra* note 16.

[20] de Vaan, Stark & Vedres, *supra* note 16, at 1150–1153.

[21] Vedres & Stark, *supra* note 19, at 1156.

[22] *See, e.g.*, Laura G. Pedraza-Fariña, *The Social Origins of Innovation Failures*, 70 S.M.U. L. Rev. 412 (2017).

electronic infrastructures that cut across disciplines, for example by creating repositories and protocols for data sharing around a common problem. It also requires mechanisms to transfer "know-how" – ways of performing experiments or delivering treatments that are often tacit (or hard to codify into written language) and, instead, require hands-on training in a particular discipline.

In the area of biomedical innovation, the US response had a promising start through the ACTIV program.[23] The ACTIV program recognized an important coordination gap in the US vaccine and therapeutics research infrastructure. In the words of its founders, "there was no true overarching national process in either the public or private sector to prioritize candidate therapeutic agents or vaccines, and no efforts were underway to develop a clear inventory of clinical trial capacity that could be brought to bear on this public health emergency."[24] This gap is unsurprising, given that more traditional market-based mechanisms for funding downstream research, such as patents and trade secrets, are woefully inadequate to incentivize investment in products like vaccines, for which the unpredictability of epidemics and the unavailability of a steady market create a large gap between potential private returns – which are low and uncertain – and public benefit – which is very high.[25] This context was ripe for the creation of alternative mechanisms for research funding. Although several alternative mechanisms for vaccine development already existed prior to the COVID-19 epidemic, the scale of the pandemic catalyzed an unprecedented level of funding, collaboration, and coordination at both the pre-clinical and clinical trial stages in the United States.[26]

[23] Francis S. Collins & Paul Stoffels, *Accelerating COVID-19 Therapeutic Interventions and Vaccines (ACTIV): An Unprecedented Partnership for Unprecedented Times*, 323 JAMA 2455 (2020); Accelerating COVID-19 Therapeutic Interventions and Vaccines (ACTIV), NIH, www.nih.gov/research-training/medical-research-initiatives/activ (last visited Jan. 7, 2023).

[24] *Id.*

[25] *See, e.g.*, Ana Santos Rutschman, Vaccines as Technology (2022). Notwithstanding this gap, several global public–private partnerships exist in the vaccine development space and many predate both ACTIV and OWS, such as Coalition for Epidemic Preparedness Innovations (CEPI) and GAVI. In this chapter, I focus my narrative on these two US-based public–private initiatives.

[26] *See, e.g.*, David Bloom et al., *How New Models of Vaccine Development for COVID-19 Have Helped Address an Epic Public Health Crisis*, 40 Health Affairs 410 (2021); Farrugia & Plutowski, *supra* note 1, at 1575 (describing several private–public partnerships in the COVID-19 response, such as the "COVID-19 Healthcare Coalition" and "Global Initiative on Sharing All Influenza Data" that "reimagine traditional organizational boundaries"); Philip Ball, *What the Lightning-Fast Quest for Covid Vaccines Means for Other Diseases*, 589 Nature 16 (2021) ("The world was able to develop COVID-19 vaccines so quickly because of years of previous research on related viruses and faster ways to manufacture vaccines, enormous funding that allowed firms to run multiple trials in parallel, and regulators moving more quickly than normal"); Bhaven N. Sampat & Kenneth C. Shadlen, *The Covid-19 Innovation Ecosystem*, 40 Health Affairs 400 (2021) (arguing that the availability of public funding for clinical trials and drug purchase precommitments during the COVID-19 pandemic represents a reorganization of traditional institutional roles in innovation funding).

The ACTIV program served as a fulcrum that connected participants across the public/private divide and across institutional boundaries, that created infrastructure to share resources, and that codified tacit knowledge by summarizing best practices and facilitating training across institutions. Each one of its core four working groups (pre-clinical therapeutics, clinical therapeutics, clinical trial capacity, and vaccines) created publicly available databases with curated information that included clinical research protocols, candidate therapeutic compounds, and emerging COVID variants.[27] The vaccines working group sought to provide crucial infrastructure to harmonize clinical trial data, allowing information about outcomes and other patient variables to be compared across trials.[28] Because COVID-19 cares little about political borders, an effective pandemic response will ultimately require global coordination and collaboration. ACTIV members were well aware of this need, seeking to coordinate their response with international public and private entities.[29] It is hard to gauge the full impact of ACTIV's global collaboration network, in large part because the role of ACTIV in the COVID-19 response has been supplanted by OWS – a much better-funded White House initiative with a different design from the ACTIV coordination network, and under the direction of the Biomedical Advanced Research and Medical Authority (BARDA), not the National Institutes of Health (NIH).[30]

This notwithstanding, ACTIV's creation of publicly available data repositories and infrastructure for data sharing, as well as its codification of tacit knowledge, are likely to have social spillover effects (in the form of best practices for future therapeutic candidate selection processes and clinical trials) that extend well into the future and greatly outweigh the NIH's initial investment (Figure 3.1).

[27] *See, e.g.*, Lawrence Corey, John R. Mascola, Anthony S. Fauci & Francis S. Collins, *A Strategic Approach to COVID-19 Vaccine R&D*, 368 Science 949 (2020); Preclinical Working Group, *Accelerating COVID-19 Therapeutic Interventions and Vaccines (ACTIV)*, NIH, www.nih.gov/research-training/medical-research-initiatives/activ/preclinical-working-group (last visited Jan. 7, 2023); Therapeutics Clinical Working Group, NIH, www.nih.gov/research-training/medical-research-initiatives/activ/therapeutics-clinical-working-group (last visited Jan. 7, 2023).

[28] *See, e.g.*, Lisa La Vange et al., *Accelerating COVID-19 Therapeutic Interventions and Vaccines (ACTIV): Designing Master Protocols for Evaluation of Candidate COVID-19 Therapeutics*, 174 Annals of Internal Medicine 1298 (2021) (describing how ACTIV brought together expertise networks that had not previously collaborated with each other, such as infectious disease and critical care, to develop master COVID-19 clinical trial protocols for the evaluation of COVID-19 therapies); NIH, *SARS-CoV-2 Vaccine Clinical Trials Using ACTIV-Informed Harmonized Protocols*, www.nih.gov/research-training/medical-research-initiatives/activ/sars-cov-2-vaccine-clinical-trials-using-activ-informed-harmonized-protocols (last visited Jan. 7, 2023).

[29] www.nih.gov/research-training/medical-research-initiatives/activ (last visited Jan. 7, 2023).

[30] Coronavirus: DOD Response, US Department of Justice, www.defense.gov/Explore/Spotlight/Coronavirus/Operation-Warp-Speed/ (last visisted Jan. 7, 2023). While Congress allocated an additional $3.5 billion to ACTIV for COVID-19 research, OWS received $15 billion.

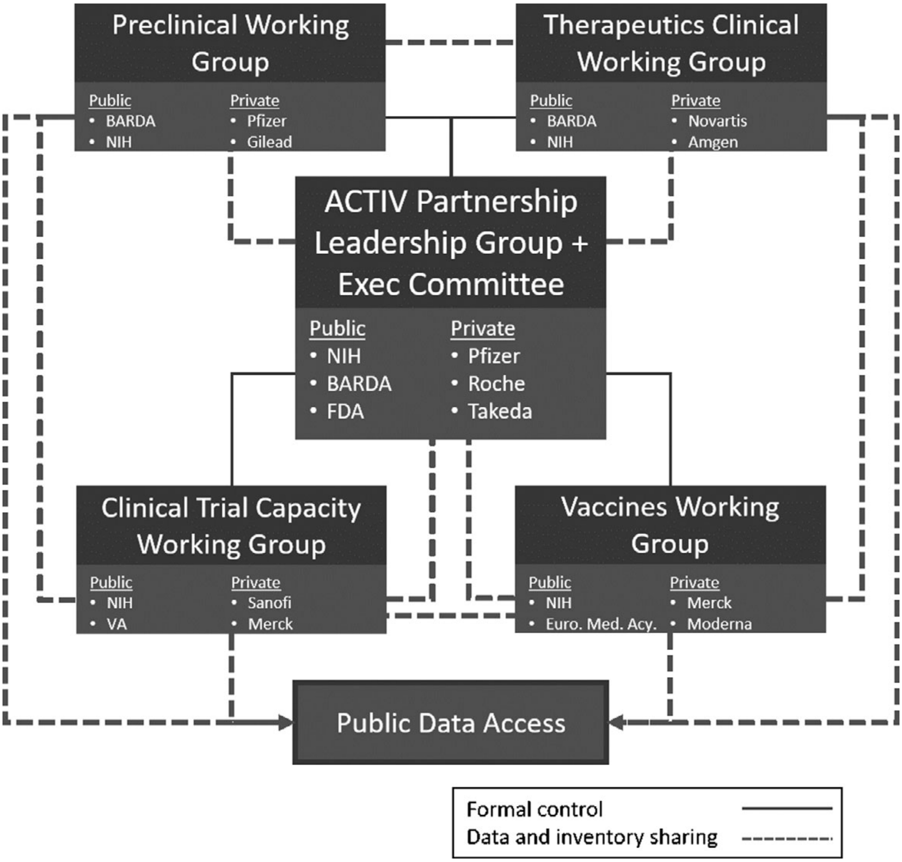

FIGURE 3.1 Accelerating COVID-19 Therapeutic Interventions and Vaccines (ACTIV) Each working group contains informal information exchange channels, with work products shared with the public in a codified manner through open access portals. ACTIV, www.nih.gov/research-training/medical-research-initiatives/activ (last visited Jan. 7, 2023).

Operation Warp Speed, an $18B collaboration between the Department of Health and Human Services (HHS), Department of Defense (DoD), and private companies, is justifiably credited with accelerating safe and effective vaccine candidates to approval for use by the US population.[31] Operation Warp Speed is, in many ways, a success story that underwrites the power of a targeted, hierarchical, command-and-control structure for vaccine development. By acting as the centralized command-and-control authority that also incorporated earlier collaborative efforts

[31] Moncef Slaoui & Matthew Hepburn, *Developing Safe and Effective Covid Vaccines – Operation Warp Speed's Strategy and Approach*, 383 New Eng. J. Med. 1701 (2020).

like ACTIV,[32] OWS effectively became the principal US vaccine effort. Although also a public–private partnership that connected many of the same players previously involved with ACTIV, OWS operated under a dramatically different model. While ACTIV fostered networked connections across the private–private and private–public divides and sought to develop infrastructure to make core information widely accessible, OWS is a centralized operation with BARDA at its core, managing bilateral, and largely secret, contracts with pharmaceutical companies.

Two features differentiate OWS's overarching structure from that of ACTIV: first, OWS's insistence on secrecy[33] and, second, its disengagement from global stakeholders (Figure 3.2).[34] It is far from clear whether OWS's centralized design and its secret bilateral contracts were key to the speed of the US vaccine response. A review of the literature suggests that two more important OWS levers were (1) its vast funding (which allowed for simultaneous, as opposed to sequential, clinical trials, process development, and manufacturing scale-up)[35] and (2) logistical expertise in global procurement.[36] What is clearer, however, is that at the leading edge of technology, innovative ideas often originate in the informal networks of learning and collaboration that cut across firms.[37] This, in turn, suggests that rapid information sharing across collaboration networks, rather than secrecy, holds the key to an effective and fast response, especially in the context of a novel virus whose defeat requires rapid technological innovation and global technological diffusion in the face of uncertainty. If OWS shifted the focus from ACTIV's largely open network of public–private and private–private collaboration to a collection of secret bilateral agreements, it also focused exclusively on a domestic response. Absent from OWS's mission is any mention of working with global partners to standardize and coordinate development, testing, manufacture, and distribution. Instead, efforts such as COVID-19 Vaccine Global Access (COVAX) have tried to fill this last gap, but without US support until recently, only an anticipated 20 percent of vaccine needs

[32] US Department of Health and Human Services, Trump Administration Announces Framework and Leadership for "Operation Warp Speed," www.defense.gov/News/Releases/Release/Article/2310750/trump-administration-announces-framework-and-leadership-for-operation-warp-speed/ (last visited Jan. 7, 2023).

[33] James Love, *KEI Sues HHS and the Army over Access to COVID-19 Contracts* (Oct. 16, 2020), www.keionline.org/34211 (last visited Jan. 7, 2023); Knowledge Ecology International, COVID-19 Contracts (containing copies of redacted contracts entered into by OWS), www.keionline.org/covid-contracts (last visited Jan. 7, 2023); Luis Gil Abinader, *Diversity of Contract Terms Illustrates Need for Transparency of COVID-19 Contracts* (Nov. 13, 2020), www.keionline.org/34543 (last visited Jan. 7, 2023).

[34] Sampat & Shadlen, *supra* note 26, at 401 ("coordination with global actors engaged in similar innovation-funding activities – in particular, China and the Coalition for Epidemic Preparedness Innova-tions (CEPI) – has been minimal").

[35] *See, e.g.*, Slaoui & Hepburn, *supra* note 31; Bloom et al., *supra* note 26, at 411.

[36] Bloom et al., *supra* note 26, at 413.

[37] *See, e.g.*, Laura Pedraza-Fariña, *Spill Your (Trade) Secrets: Knowledge Networks as Innovation Drivers*, 92 Notre Dame L. Rev. 1561 (2017).

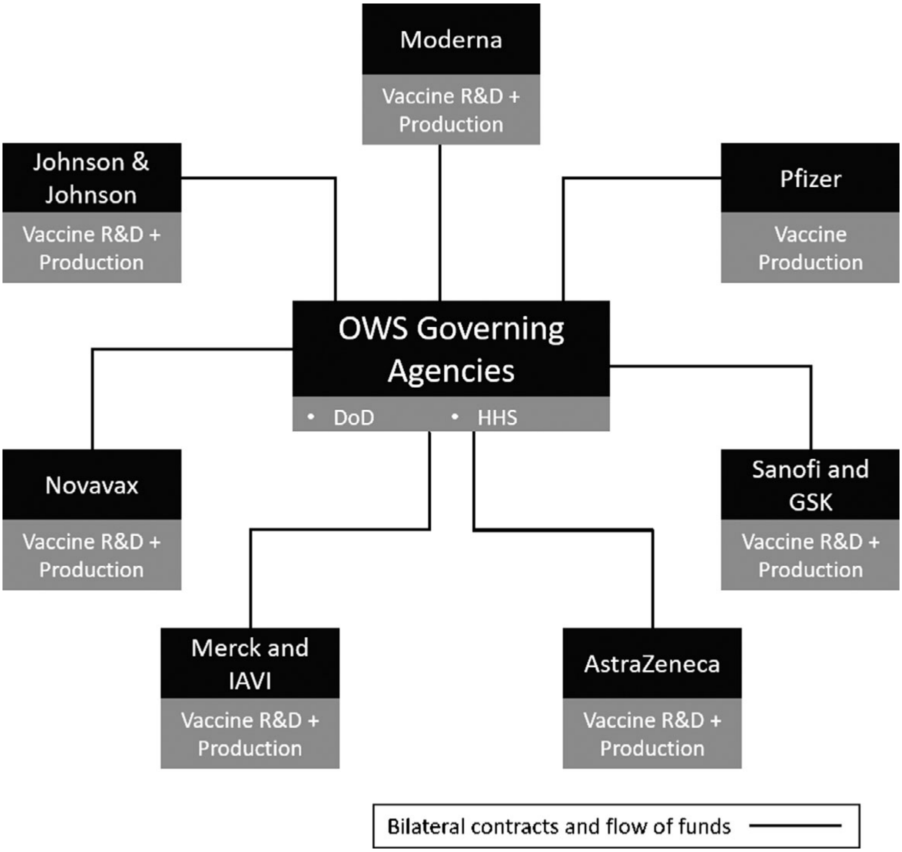

FIGURE 3.2 Operation Warp Speed
Bilateral contracts define the extent of information exchange between the government and private companies. Contracts are not transparent or available to the public. Information is not shared publicly or across participants. Nicholas Florko, *New Document Reveals Scope and Structure of Operation Warp Speed and Underscores Vast Military Involvement*, STATNEWS (Sep. 28, 2020), www.statnews.com/2020/09/28/operation-warp-speed-vast-military-involvement/ (last visited Jan. 7, 2023); CORONAVIRUS: DOD RESPONSE, U.S. DEPARTMENT OF JUSTICE, www.defense.gov/Explore/Spotlight/Coronavirus/Operation-Warp-Speed/ (last visited Jan. 7, 2023).

are expected to be met in approximately 190 countries.[38] Mistrust from this vaccine nationalism and lack of multilateral global collaboration has profound impacts – complicating the fight against more virulent variants,[39] potentially limiting post-

[38] Jeffrey D. Sachs et al., *The Lancet Commission on Lessons for the Future from the COVID-19 Pandemic*, THE LANCET (Sep. 14, 2020), www.thelancet.com/pdfs/journals/lancet/PIIS0140-6736(22)01585-9.pdf (last visited Jan. 7, 2023)

[39] Ingrid T. Katz, Rebecca Weintraub, Linda-Gail Bekker & Allan M. Brandt, *From Vaccine Nationalism to Vaccine Equity – Finding a Path Forward*, NEW ENG. J. MED. (Apr. 8, 2021), www.nejm.org/doi/full/10.1056/NEJMp2103614 (last visited Jan. 7, 2023).

vaccination travel to regions that are not politically allied,[40] and increasing vaccine hesitancy domestically.[41]

To address these challenges, and to lay the groundwork for a robust global response to future pandemics, the United States and the rest of the developed world need to do more than donate vaccine doses, facilitate bilateral transfers of intellectual property (IP), or even waive IP protection on vaccines – as crucial and as welcome as these interventions are.[42] Although several of the technologies implicated in COVID-19 vaccines are subject to patent protection, patents alone are not the most significant hurdle to worldwide vaccine availability. Even if all patent rights to COVID-related technology were to be instantly waived, the challenges to manufacturing large numbers of doses of COVID-19 vaccine would remain daunting: other drugmakers would still lack sufficient available inputs, trained personnel, and detailed knowledge about vaccine production technology, in particular with respect to the novel mRNA technology employed in the Pfizer and Moderna vaccines.[43] In other words, a key hurdle to scaling up global vaccine production is the lack of manufacturing know-how, which is often kept as a trade secret by originator drugmakers.[44] Simply waiving trade secret protection, however, would not close this gap: know-how transfer, in particular when new technologies are involved, is notoriously tricky, often requiring the type of "learning-by-doing" that can only happen through immersive training. This type of sticky know-how, also known as "tacit knowledge," is precisely the reason why licensing deals between academia and industry often include clauses that require academic scientists to remain employed as industry consultants long after the licensing deal is signed.[45]

While OWS lacked a global coordination component, HHS and DoD need look no further than their own initiatives to seize on strategies that can be adapted for know-how transfer on a global scale. For example, HHS's ACTIV promotes a model of data sharing and know-how transfer mediated by a government agency (NIH) that facilitates knowledge flows across participants and creates standardized knowledge platforms. ACTIV, however, lacked a mechanism for the type of experiential workforce training that is so crucial to the transfer of tacit knowledge, relying instead on the ability of their individual network members to train their own. When local technological capacity is limited – as is the case in global manufacturing capacity – workforce training becomes an indispensable component. Research on innovation clusters, however, suggests a solution: the creation of *regional* know-how transfer

[40] *When It Comes to a Travel Restart All Vaccines Are Not Equal*, Bloomberg, (Apr. 25, 2021), www.bloomberg.com/news/articles/2021-04-25/vaccine-travel-rules-widen-the-rift-between-china-and-the-west?embedded-checkout=true#xj4y7vzkg (last visited Jan. 7, 2023).

[41] Sachs et al., *supra* note 38.

[42] W. Nicholson Price II, Arti K. Rai & Timo Minssen, *Knowledge Transfer for Large-Scale Vaccine Manufacturing*, Science (Aug. 13, 2021), https://science.sciencemag.org/content/early/2020/08/12/science.abc9588?versioned=true (last visited Jan. 7, 2023).

[43] *Id. See also* Sampat & Shadlen, *supra* note 26.

[44] Sampat & Shadlen, *supra* note 26.

[45] *See, e.g.*, Peter Lee, *Transcending the Tacit Dimension: Patents, Relationships, and Organizational Integration in Technology Transfer*, 100 Cal. L. Rev. 1503 (2012).

hubs that geographically concentrate training, manufacturing, and innovation.[46] Although specific individual countries may not yet have the necessary technological capacity to absorb such know-how transfer bilaterally, that capacity is more easily developed at the regional level. Regional know-how transfer hubs could serve as a centralized training center for several recipient countries, both facilitating the transmission of tacit knowledge behind new vaccine technologies and helping develop local capacity by creating informal local networks of information exchange. In fact, DoD-funded manufacturing institutes, such as Advanced Functional Fabrics of America and others within the Manufacturing USA umbrella,[47] are examples of domestic regional manufacturing hubs that are based on many of these principles of hub design: geographic concentration of technological expertise; a strong focus on building technological capacity through hands-on training; a network design for the exchange of information across the public–private and private–private divide; and a central infrastructure for maintaining shared protocols and best practices. Investing in the development of regional innovation and manufacturing capacity can have important positive spillover effects for future pandemics, leading to increased regional innovation capacity with the ability to quickly adapt technological solutions to local conditions. Countries such as Indonesia, Thailand, and Vietnam provide a powerful illustration of these positive spillovers: having participated in an influenza vaccine technology transfer program spearheaded by the WHO in 2005, they are some of the only lower-income countries that are now producing COVID-19 vaccines.[48]

At the global level, the WHO has previous experience with a hub-and-spokes design for technology transfer in the vaccine space – having helped set up the Netherlands Vaccine Institute (NVI) influenza hub and the University of Lausanne's hub for the production of vaccine adjuvants.[49] Capitalizing on this experience, the WHO launched a COVID-19 mRNA vaccine technology transfer hub on June 21, 2021.[50] At the regional level, the COVID-19 vaccine crisis – and the

[46] *See, e.g.*, Pedraza-Fariña, *supra* note 37.

[47] Driving Innovation in U.S. Manufacturing, Manufacturing U.S.A., www.manufacturingusa.com/ (last visited Jan. 7, 2023).

[48] Christopher Chadwick et al., *Technology Transfer Programme for Influenza Vaccines – Lessons from the Past to Inform the Future*, 40 Vaccine 4673 (2022); *see also* Anh Duc Dang & Thiem Dinh Vu, *Safety and Immunogenicity of an Egg-Based Inactivated Newcastle Disease Virus Vaccine Expressing SARS-CoV-2 Spike: Interim Results of a Randomized, Placebo-Controlled, Phase 1/2 Trial in Vietnam* (Jun. 9, 2020), PubMed, https://pubmed.ncbi.nlm.nih.gov/35577631/; https://hanoitimes.vn/vietnam-intensifies-investment-in-covid-19-vaccines-318897.html; www.bloomberg.com/news/articles/2022-05-08/thailand-targets-homegrown-mrna-vaccine-roll-out-by-year-end (last visited Jan. 7, 2023).

[49] Martin Friede et al., *WHO Initiative to Increase Global and Equitable Access to Influenza Vaccine in the Event of a Pandemic: Supporting Developing Country Production Capacity through Technology Transfer*, 295 Vaccine A2 (2011).

[50] The mRNA Vaccine Technology Transfer Hub, www.who.int/initiatives/the-mrna-vaccine-technology-transfer-hub#:~:text=announced%20on%2021%20june%202021,the%20mrna%20vaccine%20technology%20hub (last visited Jan. 7, 2023).

stark contrast between vaccination rates in developed against developing countries – has prompted African leaders to reconsider their long-standing reliance on foreign vaccine imports.[51] The African Union has announced the creation of the Partnership for African Vaccine Manufacturing – a regional vaccine tech transfer hub with a strong emphasis on research and development through public–private partnerships that include African research universities.[52] Both of these proposals deserve robust support – both financial and logistical – from the United States and other developed countries. Finally, the WHO's COVID-19 Technology Access Pool (C-TAP)[53] also aims to increase access to technological know-how by seeking licensing agreements with pharmaceutical companies. Thus far, however, voluntary participation in C-TAP has been very limited.

The bulk of private and public investments to curb the pandemic to date have largely focused on developing vaccines and therapeutics and on solving manufacturing hurdles, but much remains to be learned about the biology of COVID-19 itself.[54] A long-term program of pandemic preparedness will require key actors to expand their focus from vaccines and therapies to understanding the underlying biological mechanisms by which COVID-19 and similar viruses interact with the immune system. Public and private actors should embrace and expand upon the types of boundary-crossing collaborations that were emblematic of the ACTIV initiative, not shelve them as a finished product following the launch of successful vaccines. Cross-cutting knowledge about mechanisms of viral infection is likely to prove crucial to efforts to prevent and treat future outbreaks. The next section summarizes likely hurdles to assembling and funding cross-disciplinary teams, together with examples of prior successful initiatives that can serve as blueprints for future funding efforts.

3 CREATING CROSS-DISCIPLINARY TEAMS AND DISMANTLING ANTI-INNOVATION NORMS

Creating infrastructures and protocols for data sharing is a first and important step in making scientific information meaningfully available across disciplines and institutional boundaries. But the problem of sticky information extends beyond creating

[51] Aisling Irwin, *How COVID Spurred Africa to Plot a Vaccines Revolution*, NATURE (Apr. 21, 2021), www.nature.com/articles/d41586-021-01048-1 (last visited Jan. 7, 2023).

[52] Lisa Schnirring, *WHO: Africa mRNA Vaccine Hub Expands to 6 Nations*, CIDRAP NEWS (Feb. 18, 2022), www.cidrap.umn.edu/news-perspective/2022/02/who-africa-mrna-vaccine-hub-expands-6-nations (last visited Jan. 7, 2023).

[53] COVID-19 Technology Access Pool, www.who.int/initiatives/covid-19-technology-access-pool (last visited Jan. 7, 2023).

[54] *See generally* Joachim S. Schultze & Anna C. Aschenbrenner, *Covid-19 and the Human Innate Immune System*, 184 CELL (2022); W. Joost Wiersinga et al., *Pathophysiology, Transmission, Diagnosis, and Treatment of Coronavirus Disease 2019 (COVID-19): A Review*, 324 JAMA 782 (2020).

platforms and protocols for efficient knowledge flow and know-how transfer. Scientists from a single community may not in fact know how to process information from other disciplines, not because it is inaccessible or tacit but because of what network scholars have termed the "cognitive distance" problem.[55] Cognitive distance problems are less about information flow and more about the ability to combine seemingly disparate pieces of information and different ways of approaching research questions into a coherent new whole.[56] In other words, solving or even framing a problem at the intersection of two or more scientific communities can rarely be accomplished by members of a single community. Rather, it requires the assembly of cognitively diverse teams that can come up with new ways to recombine existing knowledge and fresh ways to find and frame new problems, in the process creating novel thought styles and frameworks. In prior research with Stephanie Bair, we described how cognitive distance can arise from three types of social norms that emerge in scientific communities and that act to prevent collaboration across community boundaries: (1) research priorities; (2) methodology; and (3) evaluation norms.[57] Prioritizing different research questions and different ways to go about answering those questions and evaluating the quality of those answers can lead to two communities having radically-different approaches to a project – approaches that may at times appear incompatible. This conundrum – the simultaneous need for cognitive diversity and the persistent resistance to such cognitive diversity in scientific communities – has preoccupied historians, philosophers, and sociologists of science dating as far back as Ludwick Fleck and including the foundational work of Thomas Kuhn, both of whom described the evolution of science as a clash between different thought styles or scientific paradigms.[58]

What has come to be known as the "airborne vs. droplet controversy" in COVID-19 is a textbook example of the hurdles created by different research priorities, methodologies, and evaluation norms. The controversy pitted two broad communities – and their different methodology and evaluation norms – against each other. To epidemiologists and infectious disease specialists, the long-held default assumption that framed their approach was that influenza viruses (of which coronavirus is a type) spread largely through droplets and fomites, in contrast to other viruses, such as

[55] *See, e.g.*, Laura G. Pedraza-Fariña, *The Social Origins of Innovation Failures*, 70 S.M.U. L. Rev. 377, 423–424 (2017) (developing a taxonomy of innovation failures, and explaining the concept of cognitive distance).

[56] *Id.*; *see also* de Vaan, Stark & Vedres, *supra* note 18, at 1148.

[57] *See generally*, Bair & Pedraza-Fariña, *supra* note 12.

[58] Ludwick Fleck, Genesis and Development of a Scientific Fact (1935); Iliana Löwy, *Ludwik Fleck on the Social Construction of Medical Knowledge*, 10 Sociol. Health Illn. 133 (1988); Thomas Kuhn, The Structure of Scientific Revolutions (1962). For a review of sociological literature on boundary-crossing and communities of innovation, *See generally* Stephanie Plamondon Bair & Laura Pedraza-Fariña, *The Sociology and Psychology of Innovation: A Synthesis and Research Agenda for Intellectual Property Scholars*, 60 Houston L. Rev. 2022.

measles, which are aerosolized.[59] This background understanding of COVID-19 helps explain why this group of researchers more readily accepted the possibility of fomite transmission than of aerosolized transmission, even though the available evidence could support either transmission pathway.[60] Epidemiologists and public health experts also framed the relevant research question as identifying the "clinically relevant" viral transmission pathways. This framing privileged methodologies that emphasized observational and statistical analysis of real-world transmission events through techniques such as contact tracing, cluster analysis, and R naught measurements. It also implicitly rejected as somewhat suspect any evidence that was not directly tied to clinical outcomes.[61]

The members of the second group in this controversy, engineers and aerosol scientists, are in some ways outsiders to the public health policy space, with less influence on public health agendas and recommendations. In a letter to the World Health Organization, members of this group essentially called the WHO and CDC to task for a skewed analysis of the available data: arguing that the WHO had accepted incomplete information when it came to demonstrating large droplet and fomite transmission, but demanded more before endorsing measures to prevent aerosol transmission.[62] Other critics have lamented this "overly medicalized view of scientific evidence" as an approach that pays insufficient attention to data obtained from controlled laboratory experiments or computer modeling.[63]

The dynamic between these two communities reflects anti-innovation norms at play – norms that stubbornly police community boundaries and prevent cross-pollination. Much of the research on the potential for aerosol transmission of

[59] *See, e.g.*, Joshua A. Krisch, *Is the Coronavirus Airborne? Evidence Is Scant, Infectious Disease Experts Say*, Live Science (Jul. 7, 2020), www.livescience.com/coronavirus-airborne-transmission-debate.html (last visited Jan. 7, 2023) (reporting an infectious disease expert as explaining that experts "in fluid mechanics and the study of aerosols," as opposed to infectious disease experts, understand particle dynamics in controlled laboratory conditions but do not understand how particles fuel disease spread in real world environments); *COVID-19: Droplet or Airborne Transmission? Penn Medicine Epidemiologists Issue Statement*, Penn Medicine (Aug. 2, 2020), www.pennmedicine.org/updates/blogs/penn-physician-blog/2020/august/airborne-droplet-debate-article (last visited Jan. 7, 2023) ("The coronavirus airborne vs. droplet controversy appears, at this time, to involve scientists with very different perspectives on viral transmission").

[60] *See, e.g.*, *COVID-19 Transmission – Up in the Air*, Lancet Respir. Med. (Oct. 29, 2020), www.ncbi.nlm.nih.gov/pmc/articles/PMC7598535/ (last visited Jan. 7, 2023).

[61] *See, e.g.*, *COVID-19: Droplet or Airborne Transmission? supra* note 59 ("The overwhelming majority of transmission of SARS-CoV-2 is via large respiratory droplets as conclusively demonstrated by contact tracing studies, cluster investigations, the lack of infection spread in hospital settings with universal masking protocols and the low estimated R").

[62] Morawska & Milton, *supra* note 8. *See also* Apoorva Mandavilli, *239 Experts with One Big Claim: The Coronavirus Is Airborne*, N.Y. Times (Oct. 1, 2021), www.nytimes.com/2020/07/04/health/239-experts-with-one-big-claim-the-coronavirus-is-airborne.html (last visited Jan. 7, 2023) (reporting on the controversy and emphasizing the WHO's critique that it was willing to accept the idea of fomite transmission without much evidence, while using a more demanding yardstick for aerosol transmission).

[63] *Id.*

influenza viruses had been available in the engineering literature for at least the past ten years.[64] That this controversy erupted amidst the pandemic is a testament to the power of crises to reveal disciplinary clashes in methodologies and research priorities that can spend years quietly simmering beneath the surface, or not even recognized as such – due to the siloed nature of scientific disciplines. This very visible public controversy may have had the salutatory unintended consequence of revealing how the set of different research, methodology, and evaluation norms held by both communities ultimately prevented collaboration and hindered efficient public health measures.

COVID-19 has emerged, hydra-like, as a disease with many faces: the virus can be experienced either as a mild flu or as a deadly pathogen by individuals who appear – by most clinical measures – similarly healthy. Some patients recover only to experience an array of "long-Covid" symptoms, ranging from fatigue to psychiatric disorders and the sometimes lethal multi-inflammatory syndrome.[65] Scientists do not yet know why there is such an enormous variability in host susceptibility to COVID-19.[66] This uncertainty befits COVID-19's status as "one of the biggest evolutionary events in the last hundred years."[67] Our science policy strategy should similarly reflect the magnitude of COVID-19's impact on human biology. By seeking to assemble cognitively distant teams that are likely to lead to breakthrough innovation, we stand the best chance of producing the most useful knowledge about the basic mechanisms of COVID-19 function, and the development of new treatments. Difficulties in assembling cognitively distant teams, however, are bound to emerge not just in analyzing mechanisms of viral transmission but also in research attempting to understand the basic biology of COVID-19, research which to date has received less coverage and has appeared less pressing.

COVID-19 catalyzed the founding of a number of consortia, as well as the repurposing of existing ones to tackle the pandemic. Many of these consortia share several of the hallmark characteristics of successful boundary-crossing collaborations (Figure 3.3). First, COVID-19 sparked the formation of consortia organized around tackling a particular boundary-crossing problem (here, different aspects of COVID-19 infection) rather than around disciplinary lines, which is the typical structure of more traditional funding mechanisms.[68] This focus on problem-solving helped

[64] *See* literature cited in Morawska & Milton, *supra* note 8.

[65] *See, e.g.*, Bryan Oronsky et al., *A Review of Persistent Post-COVID Syndrome (PPCS)*, 12 Clin. Rev. Allergy Immunol. 4 (2021), https://pubmed.ncbi.nlm.nih.gov/33609255/ (last visited Jan. 7, 2023).

[66] *See, e.g.*, Schultze & Aschenbrenner, *supra* note 54; Ingrid Fricke-Galindo & Ramcés Falfán-Valencia, *Genetics Insight for COVID-19 Susceptibility and Severity: A Review*, 12 Front. Immunol. (2021).

[67] Schultze & Aschenbrenner, *supra* note 54, at 1672.

[68] *See, e.g.*, Laura G. Pedraza-Fariña, *Constructing Interdisciplinary Collaboration: The Oncofertility Consortium as an Emerging Knowledge Commons*, in Governing Medical Knowledge Commons 259 (2017).

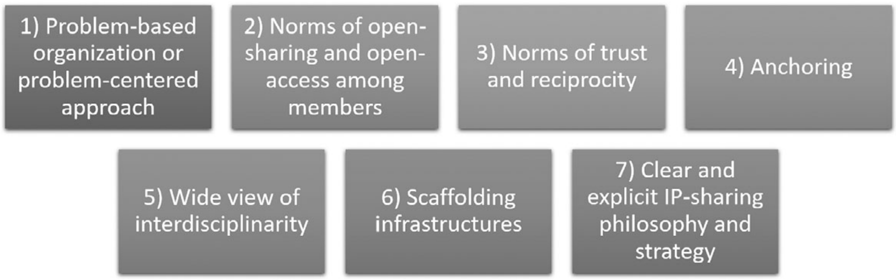

FIGURE 3.3 The hallmarks of successful boundary-crossing collaborations

collapse strong methodological preferences, and brought together experts from a wider range of disciplines.

Second, and quite remarkably, most consortia – including those with private industry leaders – have adopted an open science model for sharing both data and reagents. Take, for example, the COVID-19 High Performance Computing Consortium – an initiative spearheaded by IBM, the White House, and the Department of Energy National Laboratories.[69] The consortium was created to "provide COVID-19 researchers worldwide with access to the world's most powerful high performance computing resources that can significantly advance the pace of scientific discovery in the fight to stop the virus."[70] It relies entirely on voluntary contributions of high-performance computing resources by its members, which span the public–private divide. These resources have been put to use to model mechanisms of viral spread, to design more efficient ventilators, and to identify therapeutic targets, among other projects. Selected research projects are required to produce open results and release their data to the public. Similarly, in Europe, the Excalate4Cov consortium (a public–private partnership) has committed to open-access publishing for all of its data.[71] Two genetics consortia, the COVID-19 Host Genetics Initiative and the COVID Human Genetics Initiative, are also built upon open access to data, at least among consortium members.[72]

Finally, several consortia rely upon strong informal norms of trust and reciprocity, either by bringing together friends and colleagues who have worked together in the past, or by calling upon norms of shared sacrifice in the face of the pandemic.[73]

69 The COVID-19 High Performance Computing Consortium, https://trumpwhitehouse.archives.gov/briefings-statements/white-house-announces-new-partnership-unleash-u-s-supercomputing-resources-fight-covid-19/ (last visited Jan. 7, 2023).

70 *Id.*

71 ESCALATE4COV, www.exscalate4cov.eu/ (last visited Jan. 7, 2023).

72 The COVID-19 Host Genetics Initiative, www.covid19hg.org/ (last visited Jan. 7, 2023).

73 For example, the COVID-19 Host Genetics Initiative states that "Nothing is written in stone other than we must all act together and with no personal gain or ownership of results – just rapid and immediate dissemination of the maximum possible data and information that can be responsibly released" (*supra* note 72). Similarly, the Covid Human Gentic Effort explains that,

Commentators have celebrated the flourishing of open-sharing consortia as inaugurating a new era of widespread collaboration across the public–private scientific divide. Yet predictions that a new open-science model will enhance innovation while preserving wide access to breakthrough treatments are likely premature. Many of these consortia will need to grapple with the allocation of IP rights and the likely need for further incentives to shepherd potential treatments through clinical trials and commercialization. Preserving openness of results – while crucial for rapid follow-on innovation – is not the same as guaranteeing affordable access to treatment, since the allocation of IP rights is likely to impact pricing decisions. A long-term strategy should consider both how to make data widely available to researchers and how to ensure that resulting treatments are affordable to the public.

Consortia also need to consider structures for the dissemination of tacit knowledge beyond the confines of their core membership – structures that go beyond open-access publishing and include mechanisms for know-how transfer, as outlined in the prior section. Many of these consortia have also focused on narrow types of boundary-crossing, most notably by applying supercomputing resources and artificial intelligence tools to speed up research and discover new patterns or connections in data. We may term this type of boundary-crossing "expertise migration," which puts the tools of one community in the service of problems found in other. Although this strategy represents an incredibly fruitful tool for accelerating research, it can also fall short – without additional efforts – of creating the type of scaffold across communities that can bring diverse areas of inquiry in communication around a shared problem.

To foster the type of long-term team-building efforts that are necessary for sustained research with the potential for breakthrough innovation, additional key elements are needed. Taken together, these elements constitute the common denominator in a variety of studies of successful boundary-crossing consortia.[74] First is the involvement of a high-status intellectual actor, or an "anchor tenant" (such as a university or research institute), with a high degree of trustworthiness and a network of preexisting relationships that can increase trust and mitigate the risk of boundary-crossing projects. Second is a wider view of interdisciplinarity not only as intellectual migration but as intellectual co-production of new knowledge frameworks. Finally, some studies suggest that short-term "scaffolding" grants may be

"We are originally a group of friends and colleagues in the field of IEI, many of whom have successfully worked together on other challenges for years. We have enthusiastically welcomed the addition of new talents from this and other fields, and look forward to making new friends in these dire times, for the benefit (and glory) of humanity"; COVID Human Genetic Effort, www.covidhge.com/ (last visited Jan. 7, 2023).

74 *See*, *e.g.*, Pedraza-Fariña, *supra* note 68; Pedraza-Fariña, *supra* note 37, at 1575–1580 (summarizing studies on innovation networks and clusters); Scott Frickel & Neil Gross, *A General Theory of Scientific Social Movements*, 70 Am. Sociol. Rev. 204 (2005); John N. Parker & Edward J. Hackett, *Hot Spots and Hot Moments in Scientific Collaborations and Social Movements*, 77 Am. Sociol. Rev. 21 (2012).

sufficient to catalyze long-lasting connections across disciplinary boundaries.[75] For this reason, governmental incentives for boundary-crossing research need not be large, costly grants.

Funding agencies such as the NIH are well-placed to invest in assembling boundary-crossing teams. The ACTIV initiative highlighted earlier is a good example of how the NIH can create the type of successful scaffolding that brings together multiple players to work on a common problem. But there is another initiative in the NIH's recent history that more closely resembles the type of funding and infrastructure that would make the creation of COVID-19 interdisciplinary consortia possible. In 2001, under Director Elias Zerhouni's leadership, the NIH funded a series of interdisciplinary consortia through its "Roadmap" initiative to create the "Research Teams of the Future."[76] Zerhouni envisioned these teams as gathering "the expertise of nontraditional teams with divergent perspectives that cut across disciplines" to tackle "the puzzle of complex diseases," which each individual NIH institute, working alone, was ill-equipped to support on its own.[77]

At the time, this initiative proved controversial and was surprisingly short lived (2005–2012).[78] But in the context of the COVID-19 crisis, Zerhouni's admonition that understanding complex diseases requires the assembly of nontraditional teams appears prescient. The reasons for pushback against it – namely that scarce resources to fund principal-investigator-led projects were being siphoned away to create these "teams of the future" – are much less relevant in the face of a clear public health emergency, the specter of future pandemics, and the public willingness to target investment in research to prevent them.

4 CONCLUSION

COVID-19 has both revealed cracks in the siloed foundations of our research infrastructure and provided us with the impetus and models to correct them. The NIH, and other grant-making agencies, should encourage the creation of consortia that include broader types of boundary-crossing that go beyond using supercomputers to address disciplinary questions and that encompass potential collaborations that cut across medical, basic science, and social science disciplines. Only then will the world truly be ready to face the next pandemic.

75 Pedraza-Fariña, *supra* note 68; Parker & Hackett, *supra* note 74.

76 Elias A. Zerhouni, *The NIH Roadmap*, 302 Science 63 (2003).

77 Elias A. Zerhouni, *The NIH Roadmap for Medical Research*, presentation delivered on Feb. 27, 2004, slide 13, www.webconferences.com/nihroadmap/ppt/02%202-27%20RM%20webcast%20EZ%20final%20v.4.ppt (last visited Jan. 7, 2023).

78 *See, e.g.*, Andrew R. Marks, *Rescuing the NIH Before It Is Too Late*, 116 J. Clin. Inves. 844 (2006) ("It was irresponsible of Dr. Zerhouni to use scarce funds to support his new initiative before protecting the most tried and true mechanism for fund-ing science: the investigator-initiated RO1 grant"); Ericka Check, *Facing the Opposition*, 441 Nature (May 4, 2006) (describing criticisms of the RoadMap initiative).