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## Supplementary information

# A call to action for translational sciences in COVID-19 and future pandemics

In the format provided by the authors

**Supplementary Table 1 | Translation Together (TT) member organizations**

TT is a collaboration of translational research organizations from around the world that leverages each partner's complementary scientific and operational strengths, and shared insight of the challenges facing translation to advance the field of translational science. TT's goal is to build a global translational research community of stakeholders to effectively and efficiently translate discoveries into health interventions for the benefit of patients and society.

TT has four main objectives: (1) Educate: coordinate and develop programs and resources for educating and training the next generation of translational scientists and other key stakeholders; (2) Advocate: promote a broad understanding of and appreciation for translation and translational science among diverse stakeholders; (3) Connect: assist investigators in the conduct of translation and translational science by connecting them to resources, tools, technologies, and expertise; and (4) Collaborate: conduct collaborative research projects to remove systemic barriers and catalyze translation. Each organization approaches its mission via different operational models with geographic and societal contexts.

| Organization Name (abbrev.) | Region | Organization Summary | Funding Model |
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| AdMare Bioinnovations (AdMare) | Canada | AdMare Bioinnovations is Canada's global life sciences venture, building the Canadian life sciences industry by sourcing therapeutically and commercially promising research from leading academic and biotech partners to create new companies of scale, providing specialized expertise, infrastructure, and capital to help existing companies scale up, and driving the growth of these companies into Canadian anchors by training the next generation of highly-qualified personnel. | Funding agency & Research organization |
| European Infrastructure for Translational Medicine (EATRIS-ERIC) | Europe | EATRIS-ERIC is the European research infrastructure for translational medicine. The organization provides research services for biomedical innovation by providing fast, tailored access to cutting-edge enabling technologies in translational research. Via the EATRIS central hub, stakeholders can access the vast array of clinical expertise and high-end facilities that are available within 100+ top-tier academic centers across Europe | Research organization |
| Japan Agency For Research and Development (AMED) | Japan | AMED is a funding agency promoting integrated research and development in the field of medicine, from basic research to clinical trials, and performs a key role in supporting universities/academic institutes and improving the research environment in Japan. The goal of AMED's activity is to fast-track medical research and development that directly benefits people, not only by extending lifespan but also by improving the quality of life. To achieve this goal, AMED is organizing programs into integrated projects across the full range of disease areas. | Funding agency |
| LifeArc | UK | LifeArc drives medical innovation through their own research and work with a range of partners from industry, charities, universities, research organizations, and others involved in improving lives for patients. With a 25-year legacy of collaborating with scientists, diagnostics, and therapies, LifeArc enhances and protects innovation and advances promising research. LifeArc focuses on translation, progressing work from early lab-based findings through development so that they can benefit patients. LifeArc plays a key role in developing new treatments, medicines, diagnostics, technologies, or information resources, and turning research into practical products that benefit patients. | Funding agency & Research organization |
| National Center for Advancing Translational Sciences at the National Institutes of Health (NCATS) | US | NCATS was formed to transform the translational science process so that new treatments and cures for diseases can be delivered to patients faster. NCATS, one of 27 Institutes and Centers at the NIH, strives to develop innovations to reduce, remove, or bypass costly and time-consuming bottlenecks in the translational research pipeline in an effort to speed delivery of new drugs, diagnostics, and medical devices to patients. | Funding agency & Research organization |
| Oswaldo Cruz Foundation (Fiocruz) | Brazil | Fiocruz is the most prominent Institution of Science and Technology in Health in Latin America. Bound to the Ministry of Health, its mission is to produce, disseminate, and share knowledge and technologies, aimed at strengthening and consolidating the Brazilian Public Health System and the promotion of health and quality of life for the population. The Foundation works in all public health stages, from basic research and health care to innovation and production of supplies, such as vaccines, diagnostic kits, and drugs. | Research organization |
| Therapeutic Innovation Australia (TIA) | Australia | TIA is a national consortium of translational research infrastructure. Through TIA, Australian researchers from the public and private sectors can access a range of expertise and services to assist in the development of new therapeutic products. The TIA Consortium includes national and international expertise in the development of small molecule pharmaceuticals, biologics, vaccines, and cell and gene therapies. | Funding agency |

**Supplementary Table 2 | Examples of COVID-19 translational successes, challenges and lessons learned**
Additional details and examples of successes, challenges and lessons learned in translational science by TT partners in their responses to the COVID-19 pandemic referred to in the main text are provided below.

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| 2.1 | The National Center for Advancing Translational Sciences (NCATS) implemented the COVID-19 OpenData Portal, a public platform screening and preclinical development data (see 2.2 below) immediately and without restrictions.[1] The site makes openly available NCATS' entire and growing set of SARS-CoV-2 screening data (>10K compounds including >3K approved drugs) in real-time, including all raw screening data (600K+ data points) and full assay protocols. See https://opendata.ncats.nih.gov/covid19/ |
| 2.2 | When the therapeutic hypothesis that GS-441524, the parent nucleoside of the antiviral remdesivir, could be a viable and orally bioavailable antiviral drug for treating SARS-CoV-2 infection was raised through public discourse,[2] NCATS undertook a full preclinical study of this hypothesis in an open and pre-competitive manner, sharing results from DMPK, formulation and manufacturing, and toxicology—typically closed held data in industry—in real time on the NCATS OpenData Portal.[3] |
| 2. 3 | In April 2020, Spain administered an antigen test in nursing homes to test for infection due to limited PCR testing capacity. By then, research from Germany had already suggested that this antigen test was an ineffective method for diagnostics, but the lack of a means for data sharing prevented connecting these lines of clinical research. |
| 2.4 | In US, negative data or misinformation on the ineffectiveness of hydroxychloroquine/chloroquine was not publicly shared in time to prevent mass off-label prescription of these drugs that could cause serious and potentially life-threatening heart rhythm issues.[4] |
| 2.5 | In Japan, due to an insufficient number of specialists in vaccine development for infectious disease, funding for vaccine development in many cases went to groups in related fields like basic immunology, or in peripheral fields such as virus vector development, gene/cell therapy or genome editing. |
| 2.6 | For example, because NCATS researchers did not have access to BSL3-labs early in the pandemic, they could not conduct any live virus assays, including whole virus neutralization assays. Only having access to pseudoparticles, host-targeting and biochemical assays made it more difficult to identify antivirals from all stages of the viral life cycle (e.g., nucleoside analogs that block viral replication such as remdesivir). This also led to an uneven focus on viral entry as a primary-assayable antiviral target. While this shortage was partially mitigated by rapidly implementing programs with collaborators and contract research organizations (CROs) with BSL-3 facilities for live SARS-CoV-2 virus work, these options significantly limited assay reagent and condition choices. For instance, CROs primarily conducted cell infection assays only with cell lines that are easy to implement (e.g., Vero/Vero E6) instead of more directly disease-relevant cell lines, limiting the clinical and translational value of the data that were generated. |
| 2.7 | LifeArc had to rely on collaborators for their different expertise across the preclinical developmental pipeline and their access BLS-3/4 resources to produce candidate neutralizing antibodies ready for progression into manufacturing and pre-clinical work-up.[5] |
| 2.8 | TIA partners had trouble gaining access to the BSL-3 labs in North America that they had collaborated with prior to the pandemic because those labs' bandwidth was fully occupied studies from within region. Even though Brazil was more prepared to fight against emerging threats due to their previous experiences with infectious disease outbreaks in Zika, Dengue and Chikungunya, they still struggled with SARS-CoV-2 response. Despite the ability to quickly pivot much existing infrastructure to battle SARS-CoV-2, the limited access to BSL-3 labs and appropriate BLS-3 platforms in Brazil for animal experimentation obstructed their progress. Even their leading infectious disease researchers had to face long queues to study the virus biology or develop COVID-19 interventions in high containment biosafety labs, with only two BSL-3 labs in Brazil at pandemic start. |
| 2.9 | In Japan, insufficient numbers of trained specialists to run infectious pathogen studies became a bottleneck. Given how long it takes to acquire skills using infectious pathogens and to be certified, it was difficult to quickly spin up a rapid response without enough trained researchers even if access to BSL-3/BSL-4 labs had been available. |
| 2.10 | Australia experienced a lack of manufacturing capabilities that significantly slowed research progress. Tight border controls compounded the already scarce supply chain or sample access, causing further delays. Their experiences with vaccine production epitomized these challenges. At the onset of the outbreak, Australia lacked the infrastructure to make cGMP quality mRNA, even for viral vector cGMP manufacturing. Given that there was no existing infrastructure to do so, the Commonwealth Serum Laboratories (CSL) had to re-tool existing manufacturing capabilities in order to manufacture the University of Oxford/AstraZeneca COVID-19 vaccine for the Australian population. The pandemic thus exposed the critical gaps in the complex manufacturing network in Australia. |
| 2.11 | Brazil's vaccine production experience in the last year exemplifies the importance of having on-going expertise and access in manufacturing capabilities in non-pandemic times. In Brazil, Fiocruz and Butantan, two centenary public institutions, have produced over 94% of all doses of COVID-19 vaccines distributed in the country thus far. Fiocruz's success can be attributed to decades of dedicated infrastructure. Since 1976, Fiocruz has maintained a factory for vaccines, reagents, and biopharmaceuticals, which allowed them to accumulate the necessary expertise and qualification in these areas. As a result, they were able to establish partnerships with vaccine producers to enable production in Brazil during the pandemic. More importantly, their expertise allowed them to ensure a complete technology transfer for manufacturing the immunizing agent, guaranteeing autonomy in the production of the active pharmaceutical ingredient (API). As of July 2021, Fiocruz has distributed more than 80 million doses of vaccines to the Ministry of Health of Brazil, and they are committed to deliver more than 110 million doses by the end of 2021. In this case, despite all the problems that Brazil encountered with COVID-19, technological and productive capacity previously installed in public institutions ensured the possibility of delivering a significant volume of vaccines to its population. |

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| 2.12 | LifeArc has helped to fund the COVID-19 Drug Screening and Resistance Hub (CRUSH), which performs pre-clinical drug screening and resistance assays for SARS-CoV-2 and other viral threats in high containment biosafety facilities.[6] Fiocruz is building new BSL-3 facilities around Brazil. NCATS is establishing a combined, high containment (BSL3/4) high-throughput screening center, and building long-term anti-viral drug development program as part of the US government's Antiviral Program for Pandemics.[7] As part of the European Health Emergency Preparedness and Response Authority (HERA), the EU plans to establish flexible and scalable development, production and distribution capacities to enable adequate response to health emergencies.[8] The HERA will continue to stress the importance of having flexible and resourced financing and procurement capacities, as well as creating training programs to improve knowledge and skills in biopharmaceutical science and biomanufacturing. |
| 2.13 | From the very beginning of the pandemic, EATRIS focused on providing "ready access" across its network to COVID-19 diagnostic, therapeutic and vaccine development resources spanning the entire translational science pipeline. Upon surveying available resources, EATRIS created a dedicated, rapid-response COVID-19 Research Group to direct and match any service requests enquiries for specific expertise related to COVID-19 amongst the group. The COVID-19 partnering process matched parties together within 48 hours, and even removed the need for contracting and facilitation fees to encourage collaboration. This group ultimately developed into the EATRIS COVID-19 Research Forum in May 2020, with a shared online platform where all the resources and activities were displayed, along with relevant news item and resources of interest, including relevant funding calls, publications, data sources, and open research service, to which members could apply if they had the appropriate expertise and capacity.[9] By end of 2020, the EATRIS COVID-19 Research Forum comprised over 90 members across 43 EATRIS institutions and continues to grow in numbers and expertise, with over 30 project teams brought together for a wide range of translational projects. |
| 2.14 | A prime example were the hundreds of redundant clinical trials assessing the efficiency of hydroxychloroquine across the EU, which ultimately proved to be ineffective in treating COVID-19 patients. |
| 2.15 | At the US NIH, many labs were concurrently working on similar research projects in March and April of 2020; there was thus an obvious need to centrally organize and coordinate COVID-19 research efforts to optimize pandemic response efforts. To address this need, NCATS, the National Institute of Allergy and Infectious Diseases (NIAID), and the Office of Intramural Research co-led a rapid effort to evaluate, coordinate, and expand existing preclinical activities within the NIH. Within a month, they were able to launch a data collection form and comprehensive dashboard that became a "one-stop-shop" for information on internal SARS-CoV-2/COVID-19 projects and resources. Maintaining or expanding this type of effort to all NIH research could minimize such a hurdle in the future. |
| 2.16 | EATRIS developed a system to help create a rapid-response research group spanning the entire EU, the "COVID-19 Research Forum." To set up the group, the first task was to compile a non-exhaustive list of activities that EATRIS sites were involved in and additional targeted collaborative services they could provide for COVID-19 research projects. EATRIS made this database of COVID-19 resources available on their website to internal and external researchers, which is updated regularly.[9] This allowed EATRIS to connect researchers to available resources and facilities to facilitate their studies. At EATRIS, the COVID-19 Research Forum provided the opportunity to support the alignment and coordination of national research agendas. However, despite calls to increase coordination and reduce duplication, the Forum experienced notable lack of policy-level coordination among regions, beyond the strong attempts of the European Commission to keep the community working together with several accelerated transnational funding rounds. |
| 2.17 | In Australia, TIA implemented a voucher-style researcher access schema, called Pipeline Accelerator COVID-19, to help organize and optimize facility access by various labs conducting translational science to eliminate redundancy.[10] Researchers could apply to access facilities with biologics, cell and gene therapies, small molecules and high throughput screening capabilities within Australia's national research infrastructure core. By placing access to the technologies needed to conduct research and develop therapeutics against SARS-CoV-2/COVID-19 behind a voucher system, TIA could track translational research activities in Australia and effectively allocate limited resources to avoid duplication. |
| 2.18 | In Europe, this has been approached by establishing the HERA, an emergency plan that will tackle the short- to medium-term threats and concurrently prepare for the future. HERA is designed to act immediately and as a matter of urgency on a number of different fronts: (1) rapid detection of variants; (2) swift adaptation of vaccines; (3) setting up a European Clinical Trials Network; (4) fast-tracking regulatory approval of updated vaccines and new or repurposed manufacturing infrastructures; and (5) enable upscaling of production of existing, adapted or novel COVID-19 vaccines. This plan will help to centrally coordinate research efforts across Europe and reduce duplications. |
| 2.19 | In Europe, a sizable portion of research activities is funded through a competitive core minimal discretionary funding authority. In situations where research focus needs to rapidly reconsidered, bureaucratic barriers to repurposing already funded grants made quick pivoting impossible because labs were bound to deliver pre-set requirements on a pre-set timeline, and there were no mechanisms available for modifications. Consequently, COVID-19 research had to be funded through new funding calls, causing substantial delays and diverting work from research to writing and reviewing proposals. Similarly in other countries, including Japan, much of existing budgets were unable to be redirected or required new funding mechanisms for COVID-19-related research and development. |
| 2.20 | When government funding alone proved to be insufficient to support pandemic response, Fiocruz began a new initiative to raise funds for COVID-19 research from the private sectors. This crowdfunding campaign, using a public website, attracted atypical partners such as major banking firms to contribute their resources to public health research. Impressively, some R$100 million ($18 million USD) were raised from this effort enabling numerous otherwise unfunded COVID-19 research projects. |
| 2.21 | For example, the continuous research on coronavirus undertaken by China as part of the PREDICT funding program and the Global Virome Project enabled quick detection and characterization of SARS-CoV-2. In the US, ongoing vaccine research on related coronaviruses laid the groundwork for the swift development of mRNA vaccines targeting SARS-CoV-2. |

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| 2.22 | Knowledge on related beta-coronaviruses (e.g., SARS/MERS) would have been immensely valuable developing drug agents against SARS-CoV-2. Unfortunately, in the US research on these viruses was essentially halted after US outbreaks were resolved, and data from previous research conducted from the 2002 SARS epidemic and 2012 MERS outbreak were not easily accessible. In Japan, for example, although funding has been temporarily increased for infectious disease research as part of COVID-19 related medical research, the budget is expected to decrease again once the COVID-19 pandemic is declared as under control. |
| 2.23 | In the US, almost all of government funding for pandemic response in the first year or more was dedicated to developing vaccines. While the successful development of these vaccines, including novel mRNA vaccines, in this short time frame can be considered a triumph of modern science, much less funding until very recently was provided to support antiviral drug research. Successful development of effective, easily distributed and administered (e.g., oral tablets) and low-cost antiviral drugs over the last year would have been transformational in reducing morbidity and mortality around the world, especially in the outpatient community and prophylactic settings. |
| 2.24 | In the EU, EATRIS is now working together with multiple research infrastructures with over 180 partners, across 34 countries, to assemble the largest and most diverse research and service providing instrument to study infectious diseases in Europe. This project, ISIDORE, which was granted funding of 21 million euros in August 2021, aims to improve Europe's global service and research capacities in the face of a future pandemic. This will be achieved by providing fast access to cutting edge resources to scientific user communities for supporting their evidence-based development or adoption of countermeasures. This platform is designed to be further expanded to include infrastructures from across the globe to combine strengths and to help remove the gaps in the translational science pipeline to support diagnostic, therapeutic, and vaccine development in times during a global health emergency. |
| 2.25 | The US launched the Antiviral Program for Pandemics (APP) in June 2021, a program with over $3 billion USD in funding that will accelerate the development of a pipeline of "Phase 2-ready" antivirals for rapidly deployment in future pandemics.[7] |

**References for Supplementary Table 2:**


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