Life Sciences

SUPERMIND

MilliporeSigma

MIT CENTER FOR COLLECTIVE INTELLIGENCE

community biotechnology

INTRODUCTION

The MIT Center for Collective Intelligence, Community Biotechnology Initiative at MIT Media Lab, and MilliporeSigma convened more than 200 experts and global leaders in science, healthcare, public policy, and other sectors for a four-week exercise to address the following challenge:

How do we identify and apply the learnings from the COVID-19 pandemic to reimagine the institutions, processes, policies, and tools we use across the Life Sciences to address global health needs for all?

We activated our expert group—or "Supermind," which MIT professor Thomas W. Malone defines as a "a powerful combination of many individual minds"—to share their ideas on how to address this challenge in five domain areas:

1. **The Future of Scientific Research and Development.**
   How can we accelerate innovation in life sciences with new types of research institutions and novel modes of funding and collaboration?

2. **Flexible and Resilient Manufacturing, Supply, and Distribution Chains.**
   How can we design manufacturing, supply, and distribution channels to ensure systemic resiliency locally and globally?

3. **Disruptive Technologies.**
   What new technologies or combinations of existing technologies can most disrupt how we treat infectious, chronic, or emerging diseases?

4. **Public Health Preparedness, Sciences, and Technologies.**
   How can we not only increase preparedness for future infectious pandemics but also improve treatment of chronic disease?

5. **Science Communication.**
   How can scientific information be communicated to all in ways that are accurate, build trust, and enable widespread use and action?

Our experts submitted 136 contributions—ideas that covered a wide spectrum of topics, from identifying emerging, disruptive technologies to suggesting new modes of global, cross-sector collaboration that could strengthen healthcare systems. Both synchronous brainstorming and asynchronous idea generation methods were employed.

After the ideas had been submitted, natural language processing (NLP) tools and expert judgment were used to group them into 20 clusters of similar ideas. Participants were then invited to vote on these clusters, using two separate criteria:

1. Which clusters had the potential to drive the greatest transformation of the life sciences over the long term?
2. Which clusters would be most implementable and achievable in the near future?

For more on the project's methodology, see the Appendix. Findings from the Supermind were distilled and streamlined into this report.

After the Supermind activation had concluded, it served as the inspiration for a series of live virtual events, called Catalyst Conversations. Each featured a panel of experts from the challenge areas and explored in depth ideas developed in the online exercise. Recordings of these conversations are posted on the project webpage.

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1 Future of Scientific Research & Development

Traditional modalities of scientific research and development were significantly disrupted during the COVID-19 pandemic, and, in the pandemic's wake, new modes of collaboration and innovation have emerged. In this chapter, the Supermind explored how to accelerate the pace of scientific discovery through new technical infrastructure and enhancing the public domain and the incubator ecosystem. Augmenting the talent pipeline in the life sciences was highlighted as a critical need, along with ways to disrupt traditional disciplinary boundaries to enable novel forms of global collaboration, including via mediation through new institutions enabled by blockchain technology.

Accelerate the Pace of Scientific Discovery

The life science ecosystem should embrace diverse global communities, traditional academic and industrial partners, and open science communities to accelerate innovation. By investing in open-source software tools like electronic lab notebooks, laboratory information management systems, and other cloud-based, AI-enabled infrastructure, we could accelerate research through democratization of advanced software capabilities and enhancing collaborative research. A complementary tactic includes promoting diversity in the research community by reducing economic and technical barriers to access. This can also be accomplished by developing and establishing digital infrastructure like open-source libraries, institutional repositories, and online journal platforms.

Additionally, commercial technologies at the end of product life cycles should be brought back into the public domain to enrich and preserve knowledge for humanity, while enabling their use as fuel for the imagination of next-generation technologists. While the biotech sector has accelerated development and democratization of technologies through commercialization, novel technologies and methods consequently migrate out of the public research sphere earlier and earlier. As technologies become proprietary and significant research and development is done privately, the public record becomes increasingly anemic. What novel technologies could be developed using parts of now dead products? Potential examples could be explored in the DNA sequencing space, where the know-how underlying methods such as pyrosequencing and sequencing by ligation were substantially developed by private companies but are no longer commercially viable. Almost all commercial technologies have a foundation in public grant funding and publication. A combination of financial and regulatory (e.g., government "march in" rights) incentives could bring proprietary know-how back into the public sphere at the end of the product life cycle.

We can further accelerate the translation of innovation by enhancing the biotech startup ecosystem through the development of flexible incubator lab spaces. These incubator lab spaces function as a critical middle-ground between academic research and industrial research and development (R&D). The National Institute of Health, or other government-funded incubator spaces based on non-dilutive or equity-based access models, could provide space for proof-of-concept work necessary to bootstrap a business or secure additional Venture Capital (VC) funding. Centralized resources at such innovation centers that include entrepreneurship mentorship (licensing and legal services, business plans and business development, etc.) would further reduce barriers to access and increase quality. Growing the biotech startup ecosystem in the US will also drive additional private capital into biology R&D, overall "growing the pie" for science funding.

Similar spaces could also be focused on smart, global synchronous and asynchronous collaboration to enable ideation, as well as rapid response for fast customization and localization. Ideation can also be fueled by more platforms of collective intelligence, in particular for knowledge sharing and collaboration.

Reimagine Talent Development and Deployment in the Life Sciences

The future of life science R&D is dependent upon having a creative and engaged community of innovators, from a pipeline of new talent to activating creatives from other disciplines.

Scientific career paths should be restructured to support scientists with a variety of experiences and talent levels, not only principal investigators. Students at all levels should be incentivized to collaborate and work in diverse teams across academia and industry. Former scientists who have left labs and accumulated a wealth of knowledge could still help drive discovery; these non-practicing researchers' knowledge could be harnessed in other impactful contributing roles.

Additionally, structures should be adjusted to evaluate and reward contributions to science from talented individuals across sectors.

Build Novel Organizational Structures and the Bio Lab of the Future

Life science R&D should explore numerous types of organizational structures to accelerate innovation. Distributed autonomous organizations (DAOs), built on blockchain technology, could enable new types of organizations that run without leadership or hierarchy, and instead use a shared system of governance and consensus managed by smart contracts. A "DAO of Life Science" could be used to distill existing models of science while streamlining legacy structures that may no longer be optimal.

Working globally to breakdown disciplinary silos could create many opportunities within life science. This has the potential to manifest in a variety of ways: building an international bio-lab (like the European Organization for Nuclear Research or the European Molecular Biology Laboratory, but for the life sciences); establishing data integration centers around the world to synthesize the vast array of data; bringing together disciplines beyond life science, i.e., life sciences and biological engineering; developing new institutions to stimulate research; and facilitating rapid collaboration and communication (similar to the Massachusetts Consortium of Pathogen Readiness). As we look to work across disciplines, funding mission-oriented teams and organizations that deeply integrate social sciences and humanities will help shape broader scientific and technical research agendas.

Life science companies should invest in critical infrastructure to enable discoveries born from the recent unprecedented funding in emergent biotech. These companies could become biotech workshops of sorts, continuing to invest in development, manufacturing, and fill-finish capabilities to enable the next generation of cell and gene therapies.

Clearly Define and Prioritize the Right Problems to Solve

Humanity faces unprecedented global problems that could be solved or aided by the life sciences, from preventing the next pandemic to protecting the environment and addressing global hunger and poverty. Well-defined problems and having large-scale agreement amongst stakeholders could lead to recruitment of the appropriate experts and support their energized cooperation.

Diversity of thought, inclusivity, effective recruitment and involvement of experts, and transparent communications should be leveraged to help address worldwide crisis interventions through focused problem selection and analytical decision-making.

Identifying the vectors, indicators, and early warning signs of human and ecological impact is critical to empower eventual solutions. A future-oriented scientific community requires new tools, metrologies, or AI-capabilities to search for these unknowns.

2 Resilient Manufacturing, Supply, & Distribution Chains

Supply chain challenges were rife during the COVID-19 pandemic and continue to impact numerous industries to this day. To address these issues, the Supermind proposed several approaches to enhance supply chain resilience. Decentralization and enhanced local production were emphasized, while agile strategies for companies and industry players were proposed. The Supermind also highlighted the need for environmental sustainability, which could be achieved, in part, through circular manufacturing frameworks. The importance of distributed critical facilities was also emphasized, along with the critical need to create and maintain strategic stockpiles and support small community organizations during times of supply chain crisis.

Create Decentralized Supply Chains and Augment Local Production to Enhance Resilience

The COVID-19 pandemic revealed weaknesses in a myriad of global supply chains, from reagents necessary for critical diagnostics to basic household supplies and agriculture products. To enhance system resiliency, manufacturing and supply chains could be decentralized to enable local and regional production in times of crisis. Local community-centered systems for production and distribution could be established for certain essential products. As an example, during the pandemic, mask production was, in many cases, localized and sourced from recycled or repurposed materials to increase access and availability. Open science spaces, maker spaces, digital fabrication hubs, and other community-based manufacturing spaces are proliferating worldwide, and partnerships with established institutions to share expertise could boost and scale these local manufacturing efforts. Furthermore, such decentralized manufacturing and localized production can build community resilience and shorten supply chains, with the additional benefit of reduced CO_2 emissions.

Parts of the world that already suffer from supply challenges are at even greater risk during times of crisis and would benefit tremendously from augmented local manufacturing capabilities. For example, the local production of point-of-care diagnostics in Sub-Saharan Africa (SSA) has been proposed as a vital strategic goal for creating supply chain resilience in a region with poor access to resources. Numerous African government reports since 2000 have highlighted the potential for the synergistic benefit of expanded local industrial production of medical supplies, coupled with improvements in the coverage and quality of health-care, especially for low-income populations. Because research, development, and manufacturing occur largely outside of SSA, products are often imported into health systems in ways that are unaffordable and inefficiently used. As a consequence, the poorest and most vulnerable communities are regularly distressed by marked-up imports from wealthier nations for vital supplies like diagnostics. Therefore, supporting and building local supply chains for essential health technologies would provide local economic benefit, as well as supply chain resilience.

As an example, the Mboalab in Cameroon is a community biology lab developing open research tools that make public domain technologies accessible and available to local communities. Critical health technologies like reagent kits for molecular assays (e.g., RT-qPCR and LAMP technologies) and DNA-based diagnostic technologies (e.g., CRISPR diagnostics) for typhoid detection are being developed in collaboration with academic and non-profit partners, like the University of Cambridge and the Open Bioeconomy Lab. Such efforts could be modeled and scaled to communities around the world, particularly for lower-resourced regions that are at greater risk of supply chain disruptions.

Develop Agile Company Practices to Resist Future Shocks

In the post-COVID world, companies should allocate resources to identify internal vulnerabilities and develop more agile practices to make supply chains increasingly resilient against future shocks. As value chains have grown in complexity and companies have become increasingly global, companies should prepare themselves for occasional shocks from severe events that can impact profits in a significant way. Companies could employ a range of options for improving resilience – for example, strengthening supply chain risk management, multi-sourcing, and improving end-to-end supply chain transparency.

Additionally, network resilience could be enhanced by diverting or reallocating resources based on real-time needs and predictive analysis. The instantaneous sharing of demand data and prediction of future supply capability derived from a truly global dataset could allow future manufacturers to price a product based on how it should be most efficiently assembled. If correctly implemented, such an approach could provide systemic resilience for both the physical product and the data needed to deliver the right product to the right place, at the right time.

Finally, it should be recognized that manufacturing and supply chains can be incredibly complex, and that, during the COVID-19 pandemic, even some of the most experienced pharmaceutical manufactures struggled to produce vaccines, therapeutics, diagnostics, and other reagents. Manufacturing resilience is dependent upon myriad factors, from what is being produced and at what scale, to its intended use, safety issues, the need for speed in manufacturing, and more. A systemic approach to catalog high-value and vital products for manufacturing could be employed, convening groups of experts in manufacturing these products to clarify manufacturing goals and mitigate potential failure points.

Utilize Circular Manufacturing Frameworks to Promote Environmental Sustainability

Principles of a circular economy should be emphasized to ensure the sustainable manufacturing of bio-based products. For example, the use of non-extractive methods of sourcing raw ingredients should be prioritized whenever possible, and literacy regarding these methods should be promoted. Single-use plastics ubiquitous in the life sciences (e.g., gloves, tubes, tips) should be replaced with sustainable alternatives – for example, using biomaterials that can be locally grown or plastics that can be biodegraded or reused. Municipal solid and liquid organic waste streams could be transformed into useful bioproducts. For instance, food waste, lignocellulosic biomass, or municipal wastewater influent could be converted by insect larvae, filamentous fungi, or algae into therapeutics, food, or personal protective equipment (PPE). Such efforts could be funded at a federal level, governed by local municipalities, and operated by personnel trained at the community level.

Organize Distributed Networks of Critical Facilities

Clean room manufacturing is central to many biomanufactured products and represents a significant obstacle for startups and academic groups. A distributed network of clean room Good Manufacturing Practice (GMP) manufacturing sites could both accelerate the pace of innovation and create greater systemic resiliency for the production of these biotechnologies. Similarly, many biomanufactured and living products require specialized temperatures during shipping – both warm and cold chains. These temperature-specific chains should be further organized to connect from the network of GMP manufacturing sites to the site of patient implantation or product distribution.

Invest and Maintain Strategic Stockpiles for Emergency Response

Nations should invest in strategic stockpiles to better enable local governments and communities to rapidly acquire critical supplies amid crises. Specifically for pandemic response, in addition to PPE and ventilators, federal, state, and local governments should survey states and hospitals regarding items that were in the shortest supply during the COVID-19 pandemic (e.g., IV bags, certain medications, testing supplies, oxygen, etc.). These items should be re-stocked, maintained, and regularly inventoried to better prepare for the next pandemic.

In addition to national stockpiles, a registry of organizations and institutions with facilities, supplies, labor, and manufacturing scale-up capabilities could be created and maintained. The pandemic has demonstrated that many organizations and institutions are willing and able to pivot and assist in the scaled-up production of vital supplies in the event of emergencies. Maintaining a registry of active partners will enable such production to happen more quickly in the future.

Empower Small Community Organizations During Crises

Large health systems and group purchasing organizations have significant buying power and, during the pandemic, were able to identify and secure new supplies in large quantities very rapidly. In contrast, small community health providers, emergency agencies, and other local organizations who never previously purchased PPE faced a steep procurement learning curve during a very dynamic period. As-needed state or regional crisis purchasing organizations could enable smaller groups to gain operational efficiencies and combine purchasing power to find new vendors more quickly, securing larger orders for lower prices.

3 Disruptive Technologies

The pandemic has ushered in the arrival of new disruptive technologies, especially with RNA-based technologies, like mRNA vaccines, which were spotlighted because of their dramatic impact on society. In this chapter, the Supermind explored several categories of dis- ruptive technologies, including big data, artificial intelligence tech- nologies and novel bioengineered therapies, along with ways to streamline their development.

Big Data and Artificial Intelligence

As digitization and aggregation of health data continues to accelerate, our ability to manage large data sets and apply cutting-edge artificial intelligence and machine learning technologies shows tremendous promise for both individual care and dramatically increasing the pace of drug discovery. Artificial intelligence is already being used by scientists across numerous research institutions for applications like predicting chemical structures that could lead to better anti-infectious agents and protein-based therapies.

Blockchain technologies could be utilized to protect privacy and transparency of patient health data, though standards must be developed to ensure ethical collection and dissemination of patient-related data and information. Registries should be created to catalog the world of bio-engineered viruses and nanoparticles. With robust ethical guidelines, we should increase sharing of data within and across nations, and with public health agendas and university researchers as applicable to further a globalized understanding of public health. Registries should be created to catalog the world of bioengineered viruses and nanoparticles. Finally, repositories of data on the results of scientific experiments, including both positive and negative results, should be established.

RNA-based Therapies and Related Technologies

As prominently demonstrated during the COVID-19 pandemic, RNA-based therapies have revolutionized not only vaccine technologies, but also approaches for other therapeutics. Lipid nanoparticles show great promise in the treatment of cancer, inflammatory diseases, or other rare diseases. Nanoparticles containing anti-infectious agents coupled with appropriate imaging guidance could be used to combat infections in hard-to-reach places like the spine. Improved delivery systems enabling the delivery of unpackaged, "naked" nucleic acid, like novel voltage-based electroporation systems or ballistic gene guns, could enable delivery of RNA therapeutics without bottlenecks in manufacturing or reagent cold chains.

Bioengineered Therapies

Advanced bioengineering approaches can enable a broad range of potential future therapies, from gene and tissue repair and in vitro prosthetics to the creation of novel viruses for therapeutic delivery. Gene replacement therapies like "homology directed repair" offer advantages like permanent genomic integration and physiologically relevant gene expression levels. Designer implants with embedded cell-free systems could enable the on-demand synthesis of simple proteins. Engineered microbiomes in both the built and living environment could improve both human and ecological health. Living replacement tissues could render joint replacements obsolete, helping to address organ shortages and helping those who have suffered amputation. Molecular tools like DNA-encoded libraries, DNA-templated organic synthesis, CRISPR, and retron library recombineering are rapidly being developed to impact the world of drug discovery. "Biomicrobots" delivered via pills in the gastrointestinal tract could be activated at sites in the human body to identify and kill infected cells. In parallel with scientific work in this area, registries should be established to allow for knowledge sharing and to keep track of natural versus engineered biological components.

Streamline Development of Novel Therapies

Novel regulatory frameworks and funding mechanisms are critical to enabling the rapid development of new therapies, as proven through the rapid development of vaccines and therapies in response to the COVID-19 pandemic. Novel approaches for addressing rare disease, administering appropriate permissions for human subject research, exploring alternatives to traditional clinical trial protocols, and using real-time data are seen as having great potential to accelerate approvals of new therapies. New funding sources are also seen as important when unanticipated infectious diseases strike.

4 Public Health Preparedness, Sciences, & Technologies

As we emerge from the pandemic, numerous vulnerabilities in the global public health system have been exposed, necessitating a variety of innovations. In this chapter, the Supermind proposed ways to augment our public health resiliency by creating a new, multi-disciplinary field of "public health technology" to modernize 21st century public health infrastructure. Early warning surveillance systems for infectious disease and new diagnostic and transmission control technologies were also highlighted, along with strategies to effectively test, trace, and isolate infected patients.

Create A New Field of Public Health Technology

The coronavirus pandemic revealed multiple weaknesses in public health infrastructure, including the dearth of technology leadership and expertise in the design of public health programs, products, and initiatives. The pandemic has sparked innovative partnerships between technology, design, medical, and public health professionals to develop solutions addressing COVID-19. Collaborations generated from addressing the pandemic can serve as a model for how public health and technology experts can and must work together to respond to this global emergency as well as to future health challenges, such as the chronic disease pandemic and the effects of the climate crisis on health. These approaches can also be applied to create a more affordable, inclusive, and equitable healthcare future.

To achieve these goals, a new field of public health technology should be established with a certificate or degree program to train a generation of interdisciplinary leaders who can serve in the public and private sectors to accelerate the modernization of 21st century public health infrastructure.

Deploy Advance Warning and Surveillance Systems for Infectious Disease

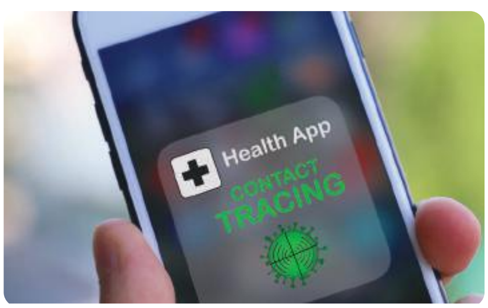
Early detection of infectious disease outbreaks for both existing and new pathogens is critical for public health resiliency. Through mass screening and surveillance testing, communities can catch outbreaks before they happen rather than being behind the curve and reacting to patients with symptoms. Inexpensive, consumer-friendly virus detectors should be developed for homes and offices. Labs and regulatory bodies should shift from traditional diagnostic testing paradigms to large-scale mass screening and surveillance testing. Wastewater testing should be integrated with public health strategies to trigger pooled community testing and rapid individual testing. Specific attention should be paid to emerging pathogens that acquire concerning properties. Population immunity could also be monitored to assess vulnerability to outbreaks.

Empowered citizens and community researchers familiar with local environments can act as “citizen sensors” to monitor environmental and societal factors important to public health.

A host of low-cost, open-source technologies should be developed, and deployed including: at-home, saliva-based molecular diagnostic tests; pulse-dose oxygen saving devices; full-face “snorkel” masks based on reusable PPE; and other associated mask technologies, like cotton-candy machines for N95 mask filter materials and low-cost particle filtration efficiency test systems.

Develop New Technologies for Diagnostics and Transmission Control

A variety of novel technologies should be developed and deployed to benefit public health. High quality, comfortable and fashionable KF94-level masks with high filtration (>99% of submicron particles blocked) should be designed and mass produced at low cost for widespread public use. Label-free sensing technologies, for example, utilized in a hand-held bioelectronic system, could be used for the rapid, high sensitivity detection of diagnostic markers for non-invasive screening tests in saliva or breath.



Implement Effective Test, Trace, and Quarantine Approaches

During infectious disease outbreaks, identifying and sequestering infected patients is a critical strategy for mitigating disease spread. Ubiquitous testing, even in resource constrained areas, can be aided by utilizing open-source protocols for testing. Fixed kits can be prone to supply chain disruptions and price increases, while robust, open-source testing protocols can allow for reagents to be substituted, if supply chains are compromised. During a pandemic, better incentive systems should be adopted to reward those who exhibit responsible public health behavior. Contact tracing capabilities at the state and local level should be augmented with funding to flexibly expand as outbreaks occur. While hundreds of exposure notification applications have been developed for contact tracing, these applications should be rigorously analyzed for efficacy and piloted for real world use.

5 Science Communication

Of critical importance to the future of the life science ecosystem is the ability to communicate scientific discoveries, both amongst the scientific community and to the public. How do we know what information is trusted and verified? How can we use storytelling to best engage communities? In this chapter, the Supermind proposed ways to battle the infodemic that has plagued public discourse during the pandemic through authentic storytelling, approaches to verify trusted information, and strategies to build trust with communities. The importance of promoting scientific literacy was highlighted, along with the significance of understanding the role of human behavior and culture in science communication.

Battle the Infodemic

In the spring of 2020, the United Nations and World Health Organization (WHO) began to speak of the infodemic — the presence of too much information, including false and misleading information, as a major barrier to addressing COVID-19. Misinformation and distrust can be a particularly toxic mix that causes people to reject health interventions, such as vaccines; disregard health guidance, as has been seen with Ebola; or try out unproven and dangerous therapies like ingesting Ivermectin to prevent COVID-19. Disinformation and misinformation can even be used to foment social and political instability, effectively weaponizing false information.

The multidisciplinary field of infodemiology should be supported to better understand the complex factors that lead to infodemics. A variety of previously disconnected disciplines should be integrated to understand the challenges of information overload, communication, design, media studies, socio-behavioral factors, misinformation, and ethics and regulation of the information ecosystem. Reproducible patterns and cross-disciplinary metrics in infodemiology should be established. The extent to which offline behavior is influenced by online behavior (and vice versa) should be researched. Coordinated education campaigns should be used to counter misinformation across platforms and through communities using traditional means, like through media advertisements and through schools, but also using newer communication platforms like social media. “Beat The Virus” is an example of a campaign that uses cutting edge data analytics to measure the impact of public health messaging.

Connect to the Public Through Authentic Storytelling

Scientific communicators should employ stories with characters who create empathy and connection and highlight shared values. Most people do not respond to data or numbers – instead, scientific communicators must foster connection through emotion using stories of hope, lessons through tragedy, and inspiration. Technical experts should work with artists and professional storytellers across media — film, TV, radio, podcasts, social media, and beyond — to share authentic messages from frontline healthcare workers, doctors, nurses, scientists, and researchers. Leveraging humor, dance, and other art forms to engage the public with targeted messaging, and connect ing to the public via genuine stories from community members, neighbors, and family members could also increase understanding.

Engage and Empower Communities to Build Trust

Trusted community champions should be trained, supported, and funded to help build reliable social networks to minimize the impacts of misinformation. As recognized by the WHO, there is an urgent need to empower communities to manage infodemics and build resilience through co-designed interventions. Community engagement rooted deeply within local cultural contexts should be used to build resilience to infodemics and misinformation at individual, community, platform, and societal levels. Community champions should disseminate accurate information through coordinated education campaigns.

Verify True, Reliable Information

Much like the blue check mark used by social media platforms like Twitter, Facebook, and Instagram, similar methods of verifying true public health and scientific information or reliable sources of information should be used. The scientific community should rally around these key sources of reliable, accurate information when communicating with the public. They should insist on fact checking for media outlets and have real penalties when inaccuracies do occur.

An active network of scientists could be established who work together to ensure scientific data is technically synthesized, validated, differentiated, and prepared for dissemination. Unlike a formal review board for a scientific journal that fact checks existing information, this group would focus on proactive communication of correct information and triage what is most important to communicate, which would then be passed to community brokers and champions.

A key component to ensuring this model's success is having expert representation in all geographies participate in the exchange. As COVID-19 has shown, it is easy to have disparate models, learnings, and information across borders, and we could resolve this challenge with regular cross-communication.

Foster Scientific Literacy

The scientific community should play a more significant, active role in fostering broader scientific literacy amongst the public. Several aspects of understanding should be emphasized, including: the science around symptoms, diagnosis, and disease transmission; why the scientific community’s advice and guidance continues to evolve; and how to distinguish between reliable and unreliable sources.

Organizations like the “News Literacy Project” should be emulated in how they incorporate media literacy into education curricula, instead employing scientists and science communicators for scientific literacy. Scientists should engage more actively in their communities, employing strategies to bridge communication gaps between scientists and non-scientists. Local school systems should partner with local universities to create science, technology, engineering, and mathematics curricula, also known as STEM, to engage students at a young age with tools that educate and inspire, like virtual reality and virtual worlds, video games, and engaging television programming, like Sesame Street. Research from organizations like the European project, RETHINK, should be built upon to design programs that promote media literacy and critical thinking skills.

Understand Human Behavior and the Role of Culture

Understanding human behavior, and the role of culture in shaping it, can help the world to address future health crises more effectively. By investing in studies of behavioral change and cultural and contextual influences, we could shift cultural distrust in science to public acceptance. We should use focus groups and participatory methods to determine how best to message and support necessary behavior changes and overcome barriers. Culture and histories of oppression affect how people receive and interpret messages and, especially when working across languages, cultures need tools that cut across barriers effectively.

APPENDIX

Appendix 1: Methodology
The Life Sciences Supermind utilized a crowdsourcing platform to spur collective thinking to address this question: **How do we identify and apply the learnings from the COVID-19 pandemic to reimagine the institutions, processes, policies, and tools we use across the Life Sciences to address global health needs for all?**

The platform engaged participants, using a variant of the xCoLab platform developed by the MIT Center for Collective Intelligence, over a four-week period. Online engagement allowed a diverse and geographically separated group to work together conveniently, rapidly, and cost-effectively. By using technology to bridge specialties, disciplines, industries, and geographies, the Life Sciences Supermind sought to develop deeper insights about the future of life sciences. The activities over the four-week exercise were as follows:

Week 1
Experts were asked to submit contributions in their domain areas, i.e., areas in which they were most knowledgeable and comfortable. Even if a participant brought a perspective from outside the life sciences (for example, they were a tech writer), they were asked to weigh in on areas outside their specific area of expertise but where they might know more based on life experience, knowledge gleaned from news sources, or ideas from their field that may intersect with the domain under consideration.

Week 2
Members of the Life Sciences Supermind were then asked to submit contributions outside of their areas of expertise. They were prompted to think creatively and suggest ideas that were outside of the box. The hope was that this would expand the breadth of ideas and push the boundaries. Throughout the process, participants were also asked to like and comment on others' contributions to highlight areas of opportunity or signify their support.

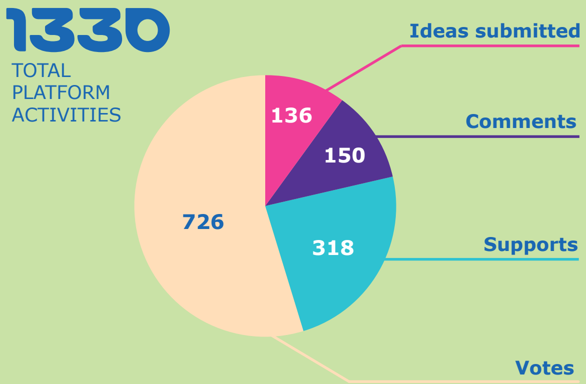
One new program component incorporated this year was a series of Super Sessions, which were synchronous sessions where participants met in live, virtual meetings. The synchronous sessions began with brief remarks by an invited expert followed by attendees being broken out into sub-groups to brainstorm together about new ideas, which were then posted to the online platform.

Week 3
The team managing the Life Sciences Supermind effort used NLP tools to group the contributions submitted during the first two weeks into 20 clusters of similar ideas. The clusters were then posted in a separate area on the platform.

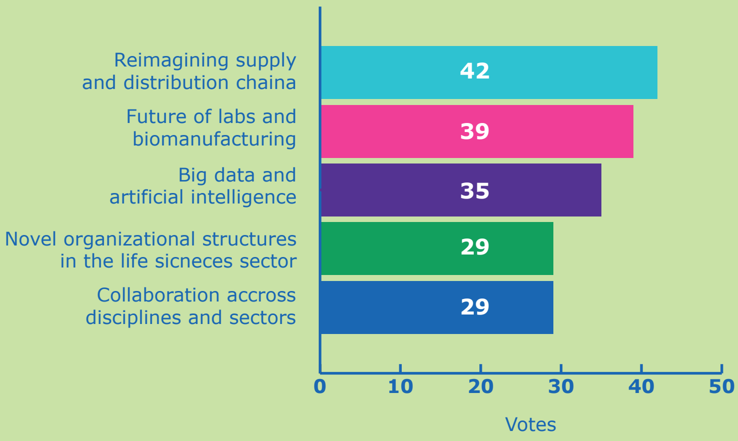
Week 4
Participants had the ability to vote on groups of contributions created by clustering the ideas generated in the first and second week. The Life Sciences Supermind participants voted on which clusters they believed would have the most long-term impact and which would be most implementable and achievable in the near term.

Life Science Supermind
BY THE NUMBERS

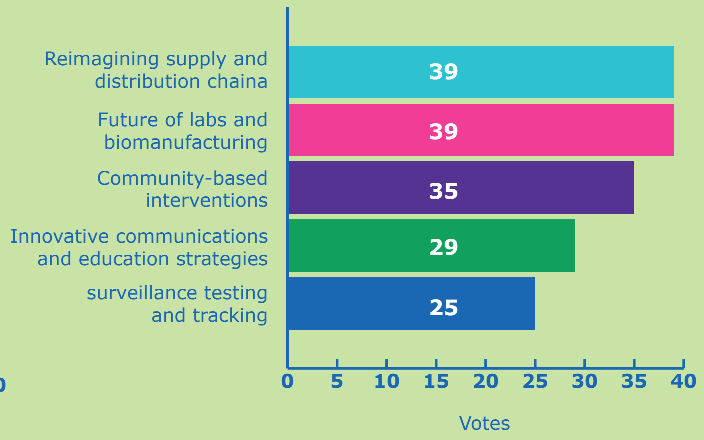
Life Sciences Supermind Activation by the Numbers



Clusters of ideas judged to have potential to drive the greatest transformation of life sciences over the long term



Clusters of ideas judged to be most implementable/achievable in the near future



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