COVID-19 and beyond: a call for action and audacious solidarity to all the citizens and nations, it is humanity's fight

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Abstract

Background: SARS-CoV-2 belongs to a subgroup of coronaviruses rampant in bats for centuries. It has caused the COVID-19 pandemic. Most patients recover, but a minority of severe cases experience acute respiratory distress or an inflammatory storm devastating many organs that can lead to patient death. The spread of SARS-CoV-2 has been facilitated by the increasing intensity of air travel, urban congestion and human contact during the last half century. Until therapies and vaccines are available, tests for virus and exposure, confinement measures and physical distancing have helped curb the pandemic.
Vision: The COVID-19 pandemic calls for safeguards and remediation measures through a systemic response. A myriad of self-organizing initiatives by scientists and citizens is developing an advanced collective intelligence response to the coronavirus crisis. Their integration forms Olympiads of Solidarity and Health. Their ability to optimize our response to COVID-19 could serve as a model to trigger a global metamorphosis of our societies with far-reaching consequences for attacking fundamental challenges facing humanity in the 21st century.
Mission: For COVID-19 and these other challenges, there is no alternative but action. Meeting in Paris in 2003, we set out to "rethink research to understand life and improve health." We have now formed an international coalition of academia and industry ecosystems taking a systems medicine approach to understanding COVID-19 by thoroughly characterizing viruses, patients and populations during the pandemic, using openly shared tools. All results will be publicly available with no initial claims for intellectual property rights. This World Alliance for Health and Wellbeing will catalyze the creation of medical and health products such as diagnostic tests, drugs and vaccines that become common goods accessible to all, while seeking further alliances with civil society to bridge with socio-ecological and technological approaches that characterise urban systems, for a collective response to future health emergencies.

The COVID-19 pandemic calls for safeguards and remediation measures through a systemic response.

The COVID-19 pandemic (Supplementary file S1), impacts on biological, social, economic and human relations. It challenges the concepts of individuality and temporality, which are entangled at all scales. It forces us to change our relationship to nature, the built environment, education, health and death. It challenges our working habits and way of life, our understanding of living organisms and their relationships to the environment, as well as our political, social, economic, production and health organizations.

Over the centuries brilliant human minds have explored the formation, organization and evolution of matter at the smallest scales, of galaxies at the largest scales, and of living systems at intermediate scales. In biology and medicine, we have not yet learnt sufficiently from the experience of astronomers and physicists who understood early on that complex systems requires the generation of enormous amounts of data to deconvolute complexity, open science international collaborations supported by common infrastructures and open data sharing to enable diverse types of analyses and multiscale modeling. The web developed by CERN to empower multiple centres to generate, access and analyze big data and exchange results, together with complementary efforts developing communication standards, enabled democratization of Internet. We need to organize similarly to understand complex and dynamic microbes-host-environment interactions, and resolve the pandemic threatening humanity (1, 2).

The complexity of SARS-CoV-2 and COVID-19 calls for a global, systemic approach. The coronavirus crisis, strikingly illustrates, as complexity theory proposes, that when a complex system is increasingly fragmented it eventually disintegrates

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(3). But with proper integrative and analytical techniques the pieces can be assembled, to a certain extent, into a comprehensive and understandable whole. The current health crisis can thus be understood and resolved only by a systemic approach placing the analytical method in the context of each individual dynamic and longitudinal big data cloud (4) to unveil dysfunctions and propose actionable solutions. The systemic approach links the complexities that interact within the same person in relation to her/his environment. This way of thinking transcends the barriers between different scientific and medical disciplines and the humanities.

It is the conjunction of the systemic and analytic approaches that will achieve the 17 sustainable development goals set by the United Nations responding to the great challenges of the 21st century: "*poverty, inequality, climate, environment, prosperity, peace and justice*" (5) while leaving no one on the side of the road, as "*every life has similar value*" (6). Indeed, in accordance with article 27 of the *Universal Declaration of Human Rights* of 1948: "*Everyone has the right to freely participate in the cultural life of the community, to enjoy the arts and to participate in scientific progress and the resulting benefits.*" The third sustainable development goal is to "*ensure healthy lives and ensure wellbeing for all at all ages*", with a special attention to the increasing burden of infectious and non-communicable diseases (NCDs) in low, middle, and high-income countries. It is clear that an infectious disease arising in any country can affect the economies of many other countries. To attain this ambitious goal and combat the current and future pandemics, a systemic approach to infectious diseases is essential to generate the data necessary for deciphering their complexity, develop global science collaborations with openly shared data, and to undertake massive joint investments for health system development that lead to intersectoral health interventions that are predictive, preventive, personalized and participatory (7, 8).

COVID-19 highlights human limitations at the individual, social and political levels. They have caused us to lose sight of these sustainable goals and could call into question our ability to achieve them. However, measures that seemed impossible to implement within one or more generations can actually be implemented in a very short time when inertia and bureaucracy are set aside for immediate action as shown by scientific and therapeutic programmes on COVID-19 performed in record time. We will no longer be able to cite as impossible the images of clear waters; animals that repopulate spaces left free by humans; deserted, pollution-free and silent cities. The COVID-19 crisis and the global response it triggered demonstrate that there can be the will to address all daunting challenges with global systemic approaches and strategic partnerships. Hopefully, history will mark the coronavirus health crisis as a turning point in moving forward towards solving others of the 21st century greatest challenges.

The health crisis is causing astounding and immediate changes. The aircraft carrier Charles de Gaulle, flagship of the French Navy, was forced to return to its home port due to a COVID-19 outbreak with more than half of the sailors infected. Such is the case aboard cruise ships and in a number of nursing homes where elderly residents are among the most vulnerable to the disease and most likely to progress to death. All these images and initiatives contrast with the short-term views and the unpreparedness of many political and economic leaders who suddenly contradicted the positions they had previously adopted. The coronavirus struck them like an electric shock, causing a painful awakening. They were accustomed to thinking and deciding in a binary manner without perceiving the complexity and uncertainty of reality. In several countries the coronavirus crisis has become bipolarizing, e.g. by demanding whether to take precautions or to ignore the disease and move on with normal life and supposedly immediate economic recovery, writing off those who die as casualties of financial success. The billions that have not been wisely invested in health research and logistics for prevention now necessitate mobilization of trillions to face the greatest economic crisis that occurred since 1870 according to the World Bank, without guarantee of quickly succeeding in addressing COVID-19 challenges.

Vocal segments of the media nourished by these events feed a self-perpetuating loop of hype for exaggerated promises or miraculous remedies promising a rapid return to the conditions existing before the start of the epidemic. The lessons learnt from previous epidemics before globalization and social media are forgotten: who remembers the million deaths caused by the second wave of flu during the winter of 1969-1970, and the two million deaths of the 1956-1958 flu pandemic? Or the multiplicity of more devastating flu pandemic waves of 1918-1920? Antibiotics and antivirals have helped diminish the burden of these diseases, although their successful use is being increasingly compromised by the development of resistant strains. The celebration the 40th anniversary of the eradication of smallpox was paradoxically obscured by a pandemic resulting from reduced alertness that led to the unfortunate reduction in will and dismantling of logistical, scientific and medical means to deal with infectious diseases outbreaks.

The Olympiads of Solidarity and Health: open and citizen science for collective advanced intelligence.

All over the world, countless individual initiatives connect people, transcending social, cultural, religious or political barriers. Confined individuals applaud the extraordinary mobilization of the caregivers who are on the front lines of service and danger. This planetary movement of solidarity extends to all those who perform the ordinary but essential services of life: food, water, communication and energy supply, maintenance and waste management, transportation and security, and teaching. Businesses and citizens from all walks of life self-organize, providing ingenious solutions to the challenges of these services in a world stalled by COVID-19.

What will be the course of this pandemic at global, regional, local and micro scales? Its development in insufficiently equipped settings could be devastating. Modelling COVID-19 data is using the same principles as those used in weather forecasting. From massive data, credible scenarios are identified in the short and medium term. Uncertainty remains, however, as to how the

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pandemic will unfold in different parts of the world, with the lack of context-aware data and knowledge gaps about the consequences of blunt public health interventions fueling real anxiety for the future.

As Charles Nicolle described nearly a century ago, all infectious diseases appear, grow and disappear (9). They can also reappear later or in new forms if our vigilance decreases or conditions are suitable. While more than 8 million cases of SARS-CoV-2 infection and 440,000 COVID-19 deaths were recorded in the world (10), the WHO now says the coronavirus may "never disappear," echoing signs that COVID-19 is becoming endemic (11). It is therefore imperative that the current, overwhelming pandemic wave be used to understand how the virus is transmitted. So far, while there are some data pointing to risk factors for death, risk factors for acquiring the virus are largely unknown and their study is limited to superficial observational inferences. However the epidemiology of the disease strongly suggests that there are gender, genetic as well as environmental risk factors.

A large part of the international scientific and medical community mobilized to accelerate understanding of SARS-CoV-2 and COVID-19. Researchers, engineers, biologists and doctors have united to facilitate the development of insights into the physio-pathology and epidemiology of COVID-19 in different environmental contexts to fight against SARS-CoV-2 and its devastating effects. A first map of interactions between the virus and human cells is available (12). Lessons should be learnt from the experience acquired during this crisis from different parts of the world, and the same fast reaction capabilities should be implemented and maintained to prevent and contain new pandemics in non-pandemic times. Many scientific and clinical areas are challenged to rapidly provide industry and health systems with credible leads to design and implement, within a few weeks and months, research projects which formerly took many years to complete. These projects involve patients and their families, authorities from different sectors including health and environment, doctors, researchers, engineers, manufacturers and all stakeholders in economic and social life. Thus, the “Olympiads of Solidarity and Health" (13) have emerged spontaneously in response to this crisis as self-organized activities based on open and citizen science committed to the free dissemination of knowledge according to best practices for the conduct of ordinary life as well as research and the dissemination of the results. The COVID-19 crisis is providing a model for how to deal with the many other crises facing society today: to create citizen science-based Olympiads and use their integrated and collective ingenuity to solve the many intractable challenges.

The COVID-19 Olympiads: advanced collective intelligence to accompany the ongoing metamorphosis.

The rapid use of “COVID-19 Olympiads” results by industrial players will serve as a basis for developing and providing doctors and sectors that influence health with effective treatments and interventions to prevent, detect, treat and cure COVID-19. The success of this endeavor will shorten the development time of treatments for other diseases and effective strategies to reduce vulnerability to disease, particularly in the context of cities where the high concentration of people and ecological disruptions increase the risk of emergence of new diseases. Such efforts will inform and contribute to the necessary transformation of our health and urban systems, reducing both healthcare costs that are becoming unmanageable and healthcare need. The power of systems medicine approaches to COVID-19 will be applied to many other diseases and ultimately to population health, thus gradually transforming 21st century medicine.

Medical and computational technologies generate the data needed to make sense of massive medical imaging, genomic and functional studies, as well as the continuous streams of big data generated by connected devices recording human activities and health statuses in real time (14). By combining human knowledge with the computing capabilities of machines, we are able to implement a collective "advanced intelligence" (15) taking into account that SARS-CoV-2 affects multiple organs sensitive to environmental variations. This often begins with infection of the lungs, heart and brain, but the liver, kidneys, intestine or skin are other possible entry points for the virus. Old age and associated comorbidities such as diabetes and obesity are aggravating factors for COVID-19 (16). Understanding coronavirus-receptor interactions and susceptibilities as well as inflammatory cascades and organ damage will lead to new and more effective solutions to combat this disease, and support advocacy for whole-of-society interventions to prevent these comorbidities.

This health-digital convergence underlies the emergence of a systemic approach to medicine, and a shift from reactive medicine, intervening after the appearance of symptoms or pathogens, to proactive medicine capable of detecting warning signs that can lead to illness. Intervention at multiple scales from individual to environmental becomes possible early to counteract the development of the disease, thus maintaining health and wellbeing of each person. The attention focused on early diagnosis, prevention and resistance will become the norm, and will require unprecedented collaborations, bridging systems biology data with data from diverse disciplines and sectors to inform intervention development tailored to different contexts.

One concrete example of the response to the COVID-19 challenge within two weeks of the first reported coronavirus infections is the clinical trial initiated by the Institute for Systems Biology (ISB) together with Swedish Hospital within the Providence Saint Joseph Health (PSJH) system, the 3rd largest, non-profit healthcare systems in the US, a speed made possible by the coronavirus crisis. This study is generating longitudinal high-dimensional data for each patient to deconvolute COVID-19 complexity by collecting billions of measurements on each individual. The study protocol includes genome/phenome analyses, very deep analyses of each individual’s immune responses and is pioneering a new approach to viral diagnosis employing saliva with an assay that is simple, rapid, inexpensive, and easy to implement (Figure 1).

This approach has attracted partners from academia, pharmaceutical, data generation, technology and diagnostic companies representing virtually all aspects of healthcare, including already thirteen different companies and academics from five different institutions joining forces to address a hard societal problem. This is creating a COVID-19 ecosystem with two components: 1)

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a platform containing a very large amount of data from COVID-19 patients and 2) partners that have agreed to immediate data release for all to be able to analyze these big data, and no initial intellectual property constraints, remarkable industrial concessions driven by the COVID-19 emergency. The same study protocol is being implemented in partnership with ISB and the European Institute for Systems Biology and Medicine at Policlinico Gemelli and San Filippo Neri Hospital in Rome, Italy, supported by an ecosystem of six academic and ten industrial partners, and by the network of translational research centers coordinated by the Jiao Tong and Fudan universities in Shanghai, China, supported by an ecosystem of fourteen academic and twelve industrial partners. These COVID-19 ecosystems will, after the crisis abates, evolve to take on similar systems-driven clinical trials on major infectious and NCDs and then quickly move seamlessly to the systems medicine analysis of millions of patients then healthy citizens. When extended to other sites, this approach will lead to a transformation of 21st century medicine and healthcare globally. We recognise the inequities in health experienced globally arise not only from inequities in access to healthcare advances but also in exposures in the natural and built environments that determine health. Therefore a critical role of this evolving ecosystem is to contribute to building stronger health systems for primary prevention (17).

Another concrete example is the OpenCovid19 Initiative on Just One Giant Lab (JOGL), an online platform designed for open science, responsible innovation and continuous learning. Launched early March 2020, it develops open-source and low-cost tools and methodologies that are safe and easy to use in response to the COVID-19 pandemic; powered by a global community of more than 4000 volunteers and experts who create solutions to better prevent, detect, and treat COVID-19, and to help forecast evolution of the pandemic. Over the course of three months, the community created 60 projects, 19 of which were awarded micro-grants through an open community peer-review system. (Figure 2).

The experience acquired during the current crisis will thus be extremely useful for the treatment of other communicable diseases, as well as for many NCDs or genetic diseases. All biomedical research domains will be transformed through foundations for a "World Alliance for Health and Well-being" (18). These will be developed in partnership with United Nations organizations such as WHO (19), UNESCO (20), UN Habitat (21), their members, industrial partners and civil society. Although health is a right to all just as is freedom from hunger, we need to recalibrate the balance between health as a right and health as a business. In the last few decades, we have seen the balance tilting in the wrong direction of ever increasing commodification of health services. Indeed, for decades, the advantages and disadvantages of an emphasis on the open commons or restricted anti-commons has fueled intense debates (22-26). We need to proactively embrace open source development of tests, drugs and vaccines as common goods of humanity, supported through innovative and realistic mechanisms to ensure their economic sustainability (27).

There will be no “day after” when all organizations and people confined voluntarily or by necessity resume their activities and habits as if nothing had happened. Our humanity, which is responsible for a cascade of events that turned into a global cataclysm, has responded by a collective attack on COVID-19. As the result, it is undergoing a metamorphosis from which a different world is emerging. Its success and future depend on us, for the better or for the worse.

Since Antiquity, every doctor has taken the Hippocratic oath at the end of medical studies. Its universally recognized principles are not to harm patients, but to relieve them while respecting their autonomy, will, integrity, dignity, and privacy in full confidentiality, without discrimination and without abusively prolonging the agonies or deliberately causing death. The goals are to promote health in all its dimensions, to be faithful to the laws of honor and probity, and to preserve necessary independence in decision making with the active participation of the patients for their benefit. This requires dedication to public education, starting in primary schools (28).

The oath of the scientists echoes and complements it prominently at the end of the luminous introduction by Michel Serres of *Le Trésor - Dictionnaire des Sciences* (29): "*For what depends on me, I swear: not to serve my knowledge, my inventions and the applications that I could draw of these to violence, destruction or death, the growth of misery or ignorance, enslavement or inequality, but to devote them, on the contrary, to equality between men, their survival, their elevation and their freedom.*"

The world that is being born from the metamorphosis caused by the COVID-19 pandemic will depend on our ability to combine these two oaths, a requirement to leverage the power of systems approaches to complex problems and the incredible transformation potential of the collective of the concerned. We hope that the generations that follow us will grow and flourish in this uncertain world and make it more fraternal, harmonious and human than the one we built, leading to the activation and the rampant spread of the new and destructive coronavirus. This will be the case only if we always remain united and vigilant during and after the health crisis that we are all going through together. This is the fight of all humanity, and we must give primary attention to the most fragile of our citizens, while making concerted efforts to reduce modifiable vulnerabilities, to preserve our most precious common good, health.

As the poet Antonio Machado put it so well, the trajectory that we will follow to embark on this extraordinary human adventure depends primarily on us: "*Caminante, no hay camino, se hace camino al andar*."

A World Alliance for Health and Wellbeing takes action through a coalition in response to the COVID-19 pandemic.

The path is not drawn in advance, we will have to adapt wisely to future circumstances. Let us show audacious and determined solidarity in taking the systems-driven measures that are essential to overcome the obstacles that hinder us. Let us bring a lasting systemic response to the global systemic crisis that challenges our certainties. There is no alternative but action. Meeting in Paris in 2003, we set out to "rethink research to understand life and improve health" (30). We now meet virtually through links

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consolidated over decades and, as a first step, have formed an international coalition to thoroughly characterize patients with COVID-19 during the pandemic using a shared study protocol and informed consent form (Figure 1). All results will be publicly available with no initial claims for intellectual property rights. This World Alliance for Health and Wellbeing has thus entered into concrete action with the mission to take a systems approach to understanding COVID-19 and to catalyze the creation of medical and health products such as diagnostic tests, drugs and vaccines that become common goods accessible to all on a sustainable basis. In addition, we recognise that many factors that determine health lie outside healthcare and that a growing majority of the world population live in cities, where the interwoven relationship between people, their environments, and emergence of disease is most apparent. As such, we further seek alliance with diverse sectors adopting systems approaches across disciplines, bridging biomedical lessons learned with the complex socio-ecological and technological systems that characterise urban systems, harnessing human and social capital for a collective response to future health emergencies.

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Keywords: COVID-19, SARS-CoV-2, coronavirus, pandemic, immune system, inflammation, systems medicine, global healthcare, call for action, international coalition.

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Figure 1: COVID-19 Immune Response

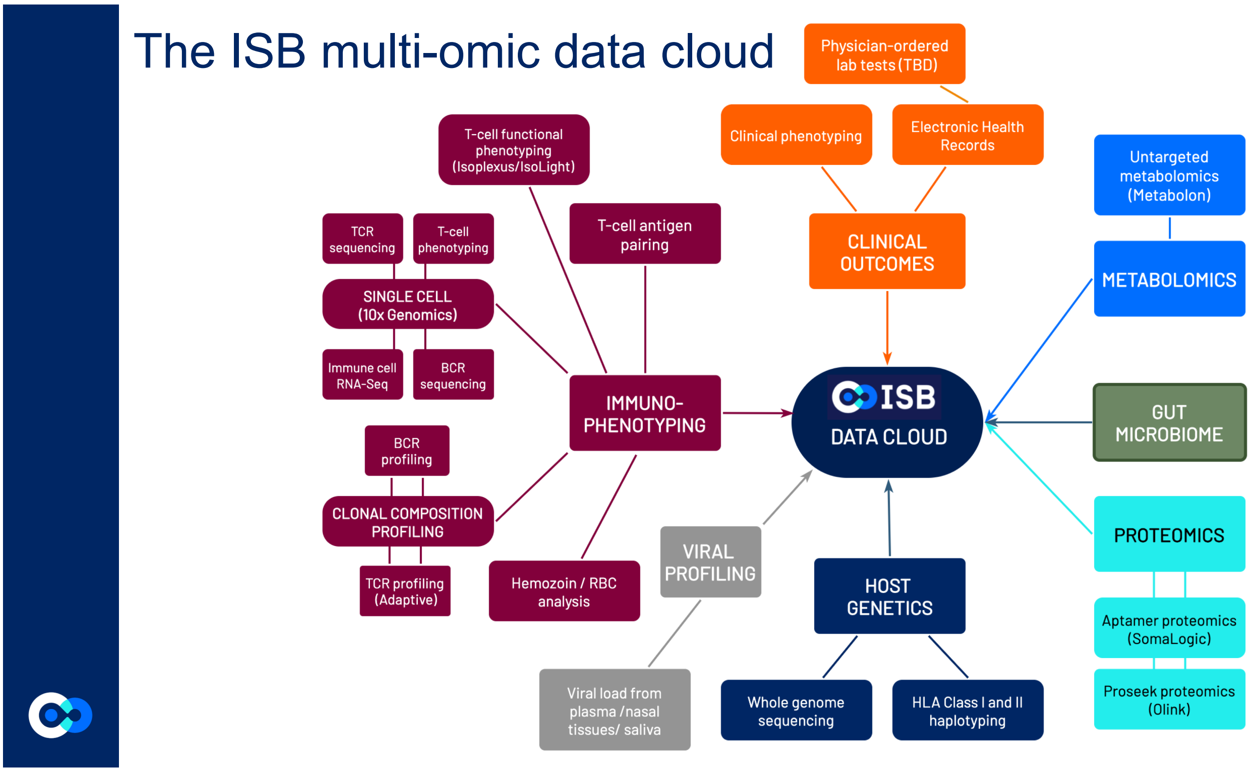

Figure 1: COVID-19 Immune Response Study (https://isbscience.org/covid19/)
Depth of the data collected and the analyses performed for each individual. The ISB/PSJH COVID-19 clinical trial started with 200 patients divided into four categories ranging from mild to most severe disease. Blood is collected at 3 times: diagnosis, 7-10 days later and after release to home; and also on patients that recovered at home. Viral infection is measured for all major organ systems. The study will be eventually extended to 600 or more COVID-19 patients at PSJH and at different locations. It employs high-dimensional analysis of SARS-CoV-2 infected individuals: genome/phenome, electronic health records, organ-specific blood proteins to determine damaged organs, and deep analyses of both adaptive and innate immune responses to identify disease trajectories as well as protective epitopes key to successful vaccines. Each patient's coronavirus RNA genome will be sequenced and their variation correlated with the patient's disease phenotypes and genome sequence. Autopsy materials from patients who have died allow identification of the various sites (and cell types) of virus infection. One thousand individuals that experienced almost two years of scientific wellness monitoring through genome/phenome analyses serve as healthy controls. These individuals provide a unique opportunity for visualization of the transition from wellness to COVID-19 for the presumptive 20-30 individuals that will have contracted COVID-19. The study will use saliva-based, high-throughput coronavirus assays for reentry in ordinary life: one very simple device and two technicians make it possible to analyze 20,000 saliva samples a day rapidly and for $2 a test. Moreover, a simple, cheap and reliable home microfluidic device is under development to determine whether one is infected with coronavirus.

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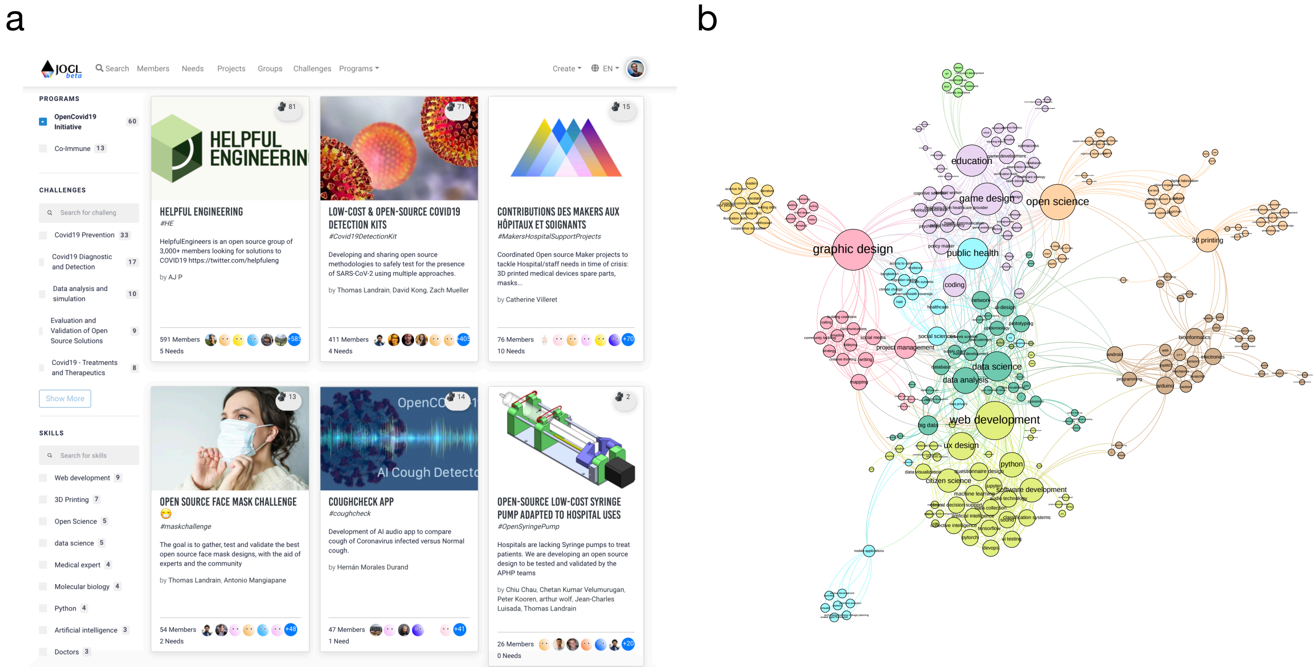

Figure 2: The OpenCovid19 Initiative on Just One Giant Lab (https://jogl.io)

- **a.** Overview of popular projects on the Just One Giant Lab (JOGL) online platform designed for open science, responsible innovation and continuous learning. Launched early March 2020, its OpenCovid19 Initiative develops open-source and low-cost tools and methodologies that are safe and easy to use in response to the COVID-19 pandemic. The OpenCovid19 program is powered by a global community of 4000+ volunteers and experts who create solutions to better prevent, detect, and treat COVID-19, and to help forecast evolution of the pandemic.
- **b.** Skill map of the OpenCovid19 community, visualized using Gephi 0.9.2. Skills are linked if they appear in a common project. Node size represents degree. Topological modules are colored using the modularity algorithm. Skills encompass a wide range of disciplines, from education and game design to public health, from project management to data science, or from web development to bioinformatics and biology.

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Supplementary file S1: State of knowledge on SARS-CoV-2 and COVID-19 (1-9)

The SARS-CoV-2 virus belongs to a subgroup of coronaviruses that have been rampant for centuries in bats. It is the cause of a worldwide pandemic of acute respiratory syndrome, the coronavirus disease 2019 or COVID-19 (10-18).

In just a few short months, a new coronavirus in the megacity of Wuhan in China's Hubei Province has shaken planet Earth and its inhabitants in a chain of events whose speed and severity seem to have taken citizens and political and economic leaders by surprise. The COVID-19 epidemic turned into a pandemic affecting almost all of the 197 states recognized by the United Nations and their associated territories (1). The number of individuals affected, which is probably largely underestimated because of the large number of asymptomatic forms that are potentially contagious, exceeds 8 millions and caused the death of more than 440,000 persons, locally saturating the health-care systems of the most affected countries, such as Italy, Spain, France, then Great Britain and the United States of America, from which the political leaders thought they were safe and which were in turn severely impacted. This is particularly true in areas where major outbreaks of contagion have caused explosive spread of the SARS-CoV-2 coronavirus. This phenomenon threatens to reach into areas with poorly developed health infrastructures, with the risk of decimating entire populations, particularly in Africa, South America and South-East Asia. African countries, with their experience of recent epidemics such as Ebola, have been quick to take strict containment measures, and have been much less affected so far because of the youthfulness of their populations (19). The same was true of the Indian subcontinent. On the contrary, Brazil is experiencing an epidemic outbreak, as is the case now in many other countries.

While most patients recover, a minority of severe forms most often associated with an inflammatory storm devastating many organs lead to the death of patients or largely unknown long-term effects for those that survive (20-22).

In many of the structures where elderly, dependent people are cared for, such as the EHPADs in France, the SARS-CoV-2 virus has caused large numbers of COVID-19 casualties. It is only recently that the victims who died in these facilities have been listed and included in a daily check-up that is constantly increasing, and we will only know the number of those who died undetected at home by comparing this year's mortality with that of previous years, as was the case during the 2003 heat wave in Western Europe. These various factors, combined with the very rapid worsening of the disease - which in its severe forms leads to the serial failure of different organs, most often starting with the lungs and producing respiratory distress - have led to an underestimation of the severity and extent of the pandemic. In order to understand how the current health emergency came about, to imagine solutions to overcome this crisis, to prevent it from continuing and worsening in successive waves due to failure to comply with containment rules, or from reoccurring with other emerging pathogens, it is essential to re-examine with the necessary hindsight the conditions that have allowed the dazzling upheavals we are witnessing.

The spread of SARS-CoV-2 and the development of the COVID-19 pandemic has been facilitated by the increased intensity of air transport, urban congestion and human contacts during the past decades.

Among the factors that have accelerated the spread of SARS-CoV-2 and transformed the initial focus of the COVID-19 epidemic into a pandemic are the considerable increase in air and land transport or the swift expansion of megacities that have become unbreathable over the last two decades due to air pollution, as has been pointed out by many commentators. As the pandemic continues to develop, it is still difficult to identify its future course. It could resemble that of the previous flu epidemic with one or several additional waves of similar or increased intensity occurring after the current one due to insufficient immunity of the population, especially given the unequal distribution of COVID-19 within regions and countries. Transfers of people from one region to another could lead to the emergence of new clusters of propagation, following one another with a temporary time lag. The pandemic may radiate to all the destinations permitted by passenger transport, and therefore unpredictably, without being subject to the physical constraints of atmospheric flows that we have gradually learned to model using massive data from measuring stations and satellite observations to feed our weather forecasts.

Until therapies and vaccines are available, tests for virus detection and seroconversion after exposure, confinement measures, social and physical distancing, and low-cost open-source methodologies are needed to curb the pandemic.

The SARS-Cov-1 epidemic in 2002-2003 was largely confined to China by the drastic measures taken by the Ministry of Health, affecting just over 8,000 people, 774 of whom died, mainly in the Canton region, but also in some 30 countries such as Canada, where it was carried by travellers. The MERS-CoV epidemic mainly affected Saudi Arabia and Middle Eastern countries such as Jordan, before being spread to South Korea by a single traveller, causing an outbreak of contagion and the death of 186 people, then affecting some 30 countries. Between 2002 and 2005, this highly pathogenic virus caused the death of nearly 500 people among the 1,400 or so infected people who could be identified.

Like all these coronaviruses and viruses in general, SARS-CoV-2 is not a self-propagating unidentified flying object. It is an inert, newly identified viral object, which is only activated when it comes into contact with animal or human cells, from which it diverts its functions in order to multiply and transmit itself through contact first between animals and humans, and then similarly between humans. SARS-CoV-2 was identified and characterized as early as the beginning of 2020, which made it possible to rapidly develop tests to detect it.

Comparison of strains isolated from different affected regions and countries showed that SARS-CoV-2 is a distant cousin of SARS-CoV-1, their common ancestor dating back to the 13th century. These studies strongly suggest that SARS-CoV-2

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originates from a reservoir of coronaviruses that have been prevalent in bats for at least 40-70 years, from which new coronaviruses may in turn emerge. SARS-CoV-2 was detected initially in Wuhan. However, since the three different clads that are prevalent in Italy are distinct from the one that predominates in France, it is well possible that several closely-related variants have come to infect humans during the recent months and years, and burgeoned simultaneously in several locations, from which it irradiated to other close or distant places through infected travellers. Indeed, retrospective exploration of health records have identified early cases during the third trimester of 2019 that remained undetected or asymptomatic.

This reversal of perspective allows us to understand that it is the organization of our economic and social life, as it has developed over the past few decades, that is at the root of the spread of these epidemics and the current pandemic. It affects a much larger number of people because of the higher contagiousness of SARS-CoV-2, but it causes proportionally fewer deaths in the population, because it is fortunately much less virulent than SARS-CoV-1 or SARS-MERS. A notable commonality between the development of these three epidemics of coronavirus disease is that their spread from the initial outbreak has occurred locally and remotely through human contact and has spread to other countries mostly through air and land travel. Epidemiological studies will help identify what other factors may have contributed to the high contagiousness of SARS-CoV-2, such as air pollution with fine particles, the simple diffusion of droplets produced by speech into ambient air, or even of the viral particles themselves (23, 24). Availability of population-based health status information provided by individuals in the field on real time through secure channels (25, 26), and platforms to provide access to virus and serocoversion testing (27, 28) will be essential for identifying local and regional outbreaks of SARS-CoV-2 and avoid further spread of COVID-19. Fast-prototyping and open-source approaches complement these actions by providing innovative, low-cost solutions that can be of particular interest for affected low-income countries.

Towards this goal, the JOGL platform for open science, responsible innovation and continuous learning is empowering partners with academic labs, companies, startups, foundations, NGOs and public services to create participatory research programs for understanding and solving health, environmental, social and humanitarian issues and currently coordinates the OpenCovid19 program fostering open-source and low-cost tools and methodologies that are safe and easy to use in response to the COVID-19 pandemic (29); the Open Source Pharma Foundation is providing an open research platform to support the development of devices, tests, drugs and vaccines to fight the coronavirus pandemic, leveraging the Open Source Discovery community (30, 31). To enable a collaborative citizen science process, researchers at the Center for Research and Interdisciplinarity (CRI) [ref.: http://research.cri-paris.org] and at OSPF [ref. 30] launch an inclusive electronic survey that allows everyone to not only to contribute their medical and well-being data in a distributed, anonymous fashion but also to debate and to contribute their own survey queries throughout the lifetime of the study, allowing participants to play an active role and tailor the survey to their own concerns and communities. Further, all raw anonymized data will be openly shared with the participants, allowing them to draw their own conclusions, discuss collectively and make informed suggestions for policy implementations locally and globally.

Links to COVID-19 resources and publications

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