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Major Global Health Issues During the COVID-19 Pandemic: Evidence-Based Medicine

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Abstract

The major global health issues that surfaced during the COVID-19 pandemic are individually addressed. As a proximate result of this analysis, the proposed creations of novel international entities such as a World Environment Organization and an International Pandemic Treaty are advocated. Further, an advanced Human Virome Project and a shift to a new health paradigm of "One World-One ecoHealth" are strongly encouraged. In addition, support is provided to a proposed blueprint for strategic pandemic prediction and prevention.

Keywords: COVID-19 pandemic; UN sustainable development goals; One-world/One-ecohealth paradigm; Global Human Virome Project; World Environment Organization; International Pandemic Treaty; Pandemic prediction and prevention.

Introduction

Since the beginning of 2022, Dr. Yann Meunier, Health Connect International (HCI), has been hosting a podcast under the theme "Reinventing global health" with sub-theme "What is wrong with global health in 2022? What are the solutions?". The podcast was sponsored by HCI, the International Institute of Medicine & Science (IIM&S), and the Society for the Advancement of Science in Africa (SASA). As part of that podcast, the author was interviewed on 4 May 2022 [1-3]. This article is an expansion of that interview, which covered thirteen important questions.

Problems with Global Health in Light of COVID-19

At least 10 (perhaps more) major problems can be identified. A full analysis of each such problem might require a separate discussion. I will limit myself here to reciting the list of problems with very brief remarks where appropriate:

We live in an unruly world of ~ 8 billion people and growing that is not easily managed.

There are glaring inequities among nations, including: the non-availability of medicines and vaccines (such as, e.g., in many African countries); insufficient health infrastructures for these countries to produce their own medicines and vaccines; stringent international standards, e.g., the World Health Organization (WHO) standards cannot be complied with; and rampant black markets for fake or sub-standard medicines and vaccines.

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The plethora of international organizations currently in existence constitute a legal and institutional landscape that is very complex and fragmented under the broad umbrella of the United Nations (UN). Thy are not operating cooperatively or in synchrony; they are focused on their own limited agendas; they are not coordinating their respective programs; they are subservient to their funders/donors; and there is no enforcement power over individual nations.

Notwithstanding its great work, during COVID-19, WHO was dilatory in not heeding early signs of the coming pandemic and taking 3 or more critical months to declare a pandemic; at times, it issued contradictory recommendations; and it deferred to powerful nations (e.g., China).

National decisions were politically driven; their international commitments barely honoured; and there were no international consequences for their action(s) or lack thereof.

There is an almost universal short memory when it comes to past history of epidemics and pandemics:

- Early signs of potential epidemics/pandemics are not heeded despite reports, briefings, warnings about viruses bearing traces of their animal origins and of emerging infectious diseases. Nations and the world remain under-prepared to predict, detect, respond, and even less prevent infectious disease outbreaks and a fortiori pandemics.
- Regarding potential future epidemics/pandemics, the underlying cause(s) have not been fully identified so that strategies for their prediction/prevention have not been devised.
- The cardinal socio-economic factors of epidemics/pandemics have heretofore not been fully identified. I have advanced 10 of them that will be discussed below.
- Epidemiological/biological modelling enabling technologies have not been sufficiently developed.

but not all is doom and gloom, I will also discuss in this article the existing positive factors and identify ways to remedy the situation.

Now, perhaps more than ever before, we should recognize and seize this moment as the most opportune time to address the prediction, management, and prevention of health crises. For this purpose and to face future health threats and pandemics, I have identified the following 10 important measures:

- Highlight global health security
- Create and strengthen necessary mechanisms
- Effectively detect and respond to emerging zoonotic threats
- Prevent pandemics and, thereby, enhance global health security
- Promote multidisciplinary engagement
- Strengthen multi-sectoral coordination
- Emphasize the importance of financial preparedness
- Improve early warning and detection
- Collect and share data in a timely manner
- Conduct laboratory testing
- Develop joint outbreak response capacities
- Take appropriate science-based actions

At this juncture, it may be instructive to remember how COVID-19 burst into the scene:

In late 2019: A group of patients with a severe acute respiratory syndrome (SARS) of unknown cause appeared in Wuhan, Hubei province, China. Since then, outbreaks of this syndrome had quickly spread across the Chinese territory, resulting in thousands of confirmed cases.

On 30 December 2019: The WHO notified the world about a pneumonia of unknown cause in Wuhan.

The Chinese Center for Disease Control & Prevention (CCD&P) then organized an intensive outbreak investigation program and attributed the etiology of this disease to a new virus belonging to the coronavirus (CoV) family. Initially, the new virus was called 2019-nCoV. Subsequently, experts from the International Committee on Taxonomy of Viruses (ICTV) renamed it SARS-CoV2 due to its similarity to the coronavirus responsible for the first epidemic of SARS (SARS-CoV) in 2002.

On 11 February 2020: The WHO announced that the disease caused by the new CoV should be called "COVID-19", which stands for "coronavirus disease 2019".

On 11 March 2020: Because of its alarming speed of

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transmission, the WHO subsequently, *albeit* somewhat belatedly, declared a pandemic state. This delay of ~ 3 months resulted in many disastrous consequences. (Note that SARS-CoV2 is not the most lethal among coronaviruses, however, its speed of propagation makes it one of the deadliest viruses known).

The Ten Socio-Economic Cardinal Factors of Epidemics/Pandemics

As painfully demonstrated during COVID-19, the health threats that devolve from the above global health problems endanger lives, disrupt families and societies, and wreak havoc on economies [4-8]. Yet, the cost of failing to control outbreaks, ruining and losing lives, destabilizing the social fabric, and decimating economies is considerably greater than the cost of prevention.

Now, from the ancestral domestication of plants and animals to the present times, we live on a microbially-unified planet. I have identified 10 intertwined socio-ecological cardinal factors that are the root causes of pandemics [9-14]. Most (hopefully all) of these factors would need to be simultaneously tackled and remedied:

- Rapid growth of global human population
- Increased globalization
- Environmental degradation and destabilization of ecosystems
- Creation of new urban or agricultural ecosystems
- Economies of scale and mono-cultures in agriculture and dysfunctional agri-food systems
- Loss of land and ocean biodiversity
- Water scarcity
- Human-induced climate change
- Societal inequities
- Irrational mass denialism of hard-won facts of science (vaccinations, antimicrobial overuse)

Some of the above factors could be correlated with the United Nations (UN) Sustainable Development Goals (SDG): factor 4 to SDG # 6; factor 8 to SDG # 13; and factor 9 to SDG # 1, 2, 3, 7, 11, 12, and 16. While important, such SDGs are not the focus of this article.

The Proposed Blueprint for Strategic Pandemic Prediction and Prevention

"Pandemic prediction and prevention" are the organization and management of appropriate measures (scientific, technical, economic, and political) to predict and prevent pandemics. It should not be mistaken for "pandemic preparedness" or "pandemic containment" or "pandemic mitigation", which largely seek to reduce the severity and negative impacts of pending or established pandemics.

Pandemic prediction and prevention seek 4 measures:

- To reduce the causes of new infectious diseases
- To prevent outbreaks and epidemics from becoming pandemics
- To prepare for potential future pandemics that could not be prevented
- To ensure that the causing virus does not re-emerge thereafter (e.g., by sustaining itself in domestic animals)

My blueprint for strategic pandemic prediction and prevention is illustrated in the flowchart of Figure 1. The proposed structure is a multi-level one (6 levels) with multi-way communication between the various levels and their components. From a top-down structure, these levels are:

- Creation of a new World Environment Organization
- Shift of the current health paradigm to a "One-World/One-ecoHealth" paradigm that will be grounded by a new International Pandemic Treaty and other international laws
- Involvement of international, intergovernmental, regional, and national health organizations
- Incorporation of the Global Human Virome Project
- Active development of models (epidemiological, climate-type) with enabling technologies and databases
- Folding-in of the development of vaccines & therapeutics and the associated research

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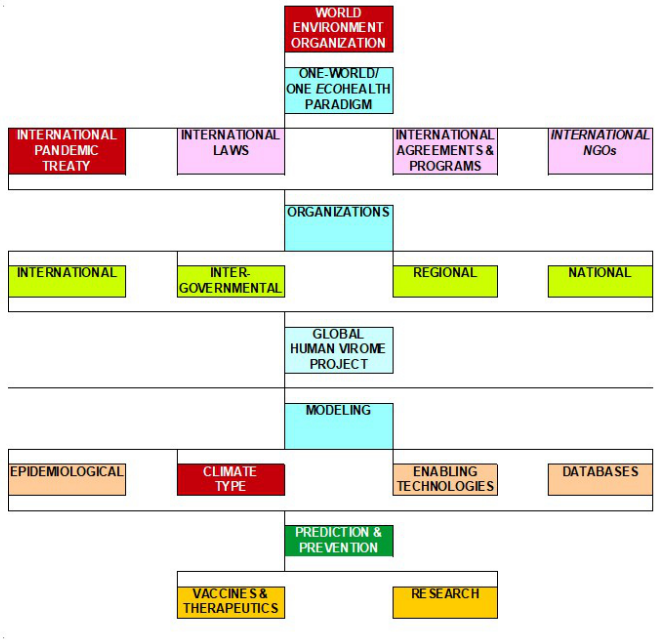

Figure 1 – A blueprint for strategic pandemic prediction and prevention

Particulars of The New World Environment Organization

With the world on a path to extreme climate change, we should perhaps reconsider and create a new regulatory agency that would have the power to censure countries for failing to keep with their commitments and pledges regarding the environment [15-20].

I join with others in advocating the creation of a new World Environment Organization (WEO) in parallel with and complementing other similar UN organizations such as the WHO, the World Meteorological Organization (WMO), and the World Trade Organization (WTO) to name some of them. There are plenty of precedents to such a creation [21-24].

If the climate and the environment were stable, we could develop public health and management strategies to deal with diseases where they occur endemically. Unfortunately, by altering the climate and the environment, we are changing the baseline and encouraging diseases to spread into new areas [25-32]. Our ability to adapt is being undermined by the way in which we continually change the environment in which we are trying to adapt. In other words, the success of responses to one disease problem is very much connected to how we solve a whole lot of other problems - a responsibility best entrusted to the WEO [32-38].

We recognize however, that in conducting its important work, like the WHO before it, the WEO will be hampered in several ways including:

- Relying on countries to timely report outbreaks
- Assuming these countries will heed WEO's advice and recommendations
- Countries may not legally commit themselves to take appropriate remedial action when it comes to ill-defined pandemics

Particulars of The New International Pandemic Treaty

Along with the new WEO, I also support and advocate for the establishment of a new, legally-binding International Pandemic Treaty (IPT) to better prepare the world for the next pandemic. This would be the next best thing pending the prediction and actual prevention of future pandemics.

In this, the Treaty will follow the creation of similar treaties. For example:

- "International Treaty on Ozone Depletion and Climate Change" (ITODCC): Warnings from researchers (including clinicians, epidemiologists, geneticists, public relations specialists, virologists, and many others) were crucial to its creation
- "Biodiversity Treaties" (BT): Non-governmental organizations (NGOs) were instrumental in its creation
- "Treaty on the Prohibition of Nuclear Weapons" (TPNW): NGOs were again instrumental in its creation

Particulars of the IPT would be, in terms of its:

- Organization: Organized under the auspices of the WHO, the Treaty would enable nations to equitably share their expertise, knowledge, and equipment in controlling and ending pandemics... and "be better prepared to predict, prevent, detect, assess, and effectively respond to pandemics in a highly

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coordinated fashion".

- Effect: The Treaty would prevent countries who are doing vaccine research (EU countries, the U.S., China, India, Russia, and others) from maintaining intellectual property (IP) on important technologies; bidding each other to find personal protective equipment (PPE) and coronavirus testing kits; and buying-up most of the stock or restricting exports to other countries.
- However, while some have recognized the compelling value of a treaty, others doubt that such an instrument would lead to a more unified and equitable response to a future pandemic. This, of course would not preclude many nations from coming together and making joint decisions of mutually beneficial interest.
- Sadly, despite the hoped-for existence of an IPT and a commitment to the principle of equitable allocations, member countries will regretfully not learn from past history and return to their past behaviour (competing with each other for supplies) when the next pandemic strikes ... unless there will not be any new pandemic!

The shift to a new health paradigm and its relevance

Our context in 2022 encompasses:

- Globalization
- Climate change
- Ecological collapse
- Species extinctions
- Interconnections among humans and animals
- Human overpopulation
- Huge economic and political disparities
- Unintended consequences of well-meaning interventions

The above factors have created a perfect storm for new pandemics [39-44]. To alleviate/eliminate them, it is imperative to extend the current "One-World" paradigm to that of "One-World, One-Health", or better yet "One World-One ecoHealth" paradigm. For this, we need to palliate most or preferably all the cardinal factors that undergird pandemics. We further need to develop the needed infrastructures and the national/ regional/ international organizations to pursue this global health agenda [45-52].

Fortunately, the contentedness among humans that now exists through communication and information technology gives us an unprecedented capacity to catch outbreaks early [53-60]. When combined with advances in our ability to study the diversity of the tiny life forms that cause epidemics and pandemics, this makes us optimistic about the future of predicting and preventing pandemics [61-68].

Current international laws, programs, and agreements that may help in the creation of the World Environmental Organization and the International Pandemic Treaty

Some of these laws, programs, and agreements includes:

- "Montreal Protocol" (MP) of 1987), which aims to phase out ozone-depleting chemicals
- "Paris Climate Agreement" (PCA) of 2018, including the "Climate Action Tracker" (CAT), which is an international consortium of scientists and policy specialists that monitors efforts to implement the Paris accord
- UN's "World Water Development (WWD)" Report, which was created to palliate the prediction that, by 2050, at least one in four people is likely to live in a country affected by chronic or recurring shortages of freshwater
- "Infectious Disease Program" (IDP)
- (US) Sequencing for Public Health Emergence Response Epidemiology and Surveillance) program (SPHERES)

The Numerous International, Intergovernmental, Regional, and National Organizations Do Not Work Well Together

The existing numerous international, intergovernmental, regional, and national organizations all suffer from some of the 10 factors I have discussed earlier. I have presented and discussed these several organizations in my book on Pandemics to which I refer the readers for complete details. These various organizations operate in a legal and institutional landscape that is very complex and fragmented. While, on the face of it, they may pursue a global health agenda, unfortunately they do not always do so cooperatively or in synchrony [69-75]. Under the broad umbrella of the UN, they include 10 international

organizations: 4 UN Decades; 4 intergovernmental organizations; 2 regional organizations; a variety of (US) Presidential Executive Orders and Initiatives; 4 (US) Federal institutions plus an additional 9 other federal COVID-19 resources; and 8 multinational nongovernmental organizations [76-85]. Notwithstanding this extensive list, it remains that we still have not developed the means to predict and prevent future pandemics. In addition, the level of investment from industry is not commensurate with the threat. Other investments could and should also come from non-profit organizations, foundations, and other stakeholders. More details on these organizations are provided in Appendix 1.

The Global Human Virome Project

After decades of reacting to each of the past pandemics, we remain only marginally better protected against the next ones. In this, we are undermined by our poor understanding of the diversity and ecology of viral threats, and of the drivers of their emergence [86-90]. One promising idea is to develop a global atlas of pathogens that are, as yet, unknown but might threaten humanity already or are likely to evolve into clear threats. Such an atlas would be a foundational necessity for anticipating and reducing the threats, but it would also be ambitious and costly, even if it was restricted initially to viruses.

Thus, the Global Human Virome Project (GHVP) was officially launched in 2018 to help identify the bulk of the viruses that threaten us (more than 1.5 million mammalian and waterfowl viruses, spanning across 25 viral families). Of these, between 631,000 and 827,000 (actually one million or more) unknown viruses might be zoonotic (i.e. of animal origin) and, thus, have the potential to infect humans after spillover from host animal populations.

The GHVP is aimed at providing timely data for public health interventions against future pandemics thus offering a pathway to improve our capacity to detect, diagnose, and discover viruses that potentially pose threats to human populations, particularly in low- and middle-income countries. The big idea is to gradually and systematically build a global atlas of most of the planet's naturally-occurring potentially zoonotic viruses.

Broadening the knowledge base on viral sequences, geographical ranges, and host distributions would provide vital intelligence about humanity's formidable microbial enemy [90-96].

Additionally, the GHVP would complement ongoing efforts, such as the “Coalition for Epidemic Preparedness Innovations (CEPI)”, the “International Vaccines Task Force (IVTF)”, and the World Bank's REDISSE program for surveillance and preparedness capacity-building projects.

Although there is a debate in the scientific community about whether the animal-human infectious disease nexus warrants substantially more funding, science effort, and global policy discussion, it remains that the GHVP could provide:

- Early warning of future threats
- Data to improve prevention and reduction of these threats
- Inputs for advance preparation of responses for unexpected outbreaks of unknown diseases

Pandemics Modelling

There are two general types of modelling: epidemiological and climate/ weather prediction.

Epidemiological Models

Genomic epidemiology is the genomic tracking and surveillance of viruses and their variants. On a global scale, this type of surveillance is currently patchy, which may be worrying because variants may be spreading undetected. We have witnessed and continue to witness such a spreading with COVID-19 [97-99].

Now, genomic surveillance is crucial to quickly identify and track emergent strains. It can also pin down how transmission occurs between individuals more definitively than typical contact-tracing can do. To be effective, however, the sequencing needs to be widespread, standardized, and embedded in national and international pandemic prevention programs. The key here is the sequencing and sharing of enough genomes to track mutations and variants of concern as they arise. As of March 2021, more than 610,000 SARS-CoV2 samples

were sequenced and could well reach and exceed one million by the end of the pandemic. These genomes could help us understand the spread of the virus through communities and across the globe, allowing us to stall infections. Unfortunately, that goal may not be fully achieved because of the limitations of current modelling [100].

My remarks here apply to only some models. For instance, "CovidSim", a computer model developed at Imperial College, London by a team of researchers headed by Neil Ferguson, was employed by the British Government to introduce lockdowns for the purpose of reducing the morbidity and mortality of the pandemic. Actually, governments utilize (or should have utilized) several different models, and compared and synthesized their results to guide them in their policy-making decisions. However, other researchers headed by Peter Coveney of the University College, London suggested that the above results were overestimated for the following reasons related to CovidSim's design, specifically:

- There are too many parameters, actually 940 parameters (only 19 of which affect the output of the numerical simulation). These parameters are sensitive to small changes in their input values that could have an outsized non-linear impact on the model's output
- There is a lack of an ensemble-modelling approach (Bayesian statistical tools analogous to weather forecasting)
- There are differences in model results: Up to two thirds of the differences in the models are due to changes to just 3 key variables: the length of "(1) the latent period during which an infected person has no symptoms and cannot pass the virus on [not actually true]; (2) the effectiveness of social distancing; and (3) how long after getting infected a person goes into isolation"

Now, how are outbreaks charted? Mathematical biologists and genetic epidemiologists develop national, regional, and world models of viral transmission. These numerical simulations could be used advantageously to further refine the risks presented by societies. An improved epidemiological model has been used which has following characteristic:

- Refines the 3C's (Closed-spaces, Crowded-places, Close-contact settings) prescription
- Tracks transmission dynamics
- Identifies risky venues and anonymized mobile phone locations

Refines the risks presented by several businesses, targets them mostly, and not further disrupts other businesses. It remains, however, that risk cannot be easily quantified with the required granularity. Because of the way our societies are organized and structured, there will always persist certain levels of super-spreading risks. Thus, many researchers suspect that, with their staggering biodiversity, tropical rainforests (such as, specifically, the Amazon in Brazil) are the most likely cradle of dangerous new pathogens. Urban growth, highway expansion, hydroelectric dam construction, mining for gold, and deforestation for cattle ranches and small farms, etc. erode the jungle and bring humans and wildlife into ever closer contact. By monitoring local animal populations and human patients, researchers hope to head off zoonoses before they spiral out of control. Their work highlights the importance of curbing human activities that boost the risk of spillover. This underscores the need to stop destroying the rainforest and keep monitoring the jungle for dangerous diseases.

Contact tracing digital apps have been deployed in many countries. They have been used to identify people exposed to the SARS-CoV2 coronavirus so as to slow down or even stop its onward transmission. In addition, the strategy called "Cluster-focused backwards contact-tracing" traces the transmission lines of infection from their source(s) to identify those individuals who might have been infected in a super-spreading event.

Climate/Weather Prediction-Type Models

I join David Adam who, in his 11/26/2020 article in Nature (pages 533-4), recommended that "epidemiologists predicting the spread of COVID-19 should adopt climate modelling methods to make forecasts more reliable". However, I want go beyond him in not limiting the model to only the current pandemic but to potential future pandemics and additionally adopt weather prediction models.

Something no less than the WMO programs and tools are needed, such as:

- Global Atmosphere Watch Program
- Global Climate Observing System
- Global data processing and forecasting system

We should take advantage of WMO's long experience in the matter of global surveillance and data analysis.

Enabling Technologies for Pandemic Prediction and Prevention

In 2012, Morse et al. claimed that: "new mathematical modeling, diagnostic, communications, and informatics technologies can identify and report hitherto unknown microbes in other species, and thus new risk assessment approaches are needed to identify microbes most likely to cause human disease".

The study investigated challenges in moving the global pandemic strategy from response to pre-emption [101]. Note, however, that despite recent advances in pandemic modeling, some experts using mostly experience and intuition have been more accurate in predicting the spread of disease than strictly mathematical models. Enabling technologies include:

- "Early warning system and artificial intelligence" (EWS/AI) to construct pathogen detection mechanisms; also, for surveillance and outbreak investigation by identifying common features and developing countermeasures and vaccines against whole categories of viruses.
- Machine learning (ML) to predict viral evolution. In April 2020, researchers developed a predictive algorithm, which can show in visualizations how combinations of genetic mutations can make proteins highly effective or ineffective in organisms, including for viral evolution like that for the SARS-CoV2 virus.
- Artificial "global immune system-like" that includes pathogen detection may be able to substantially reduce the time required to take on a bio-threat agent. The system should also involve a network of well-trained epidemiologists who could be rapidly deployed to investigate and contain an outbreak.
- Prophylactic Antiviral Crispr in huMAN cells) (PAC MAN). This is a CRISPR-Cas13d based immune subsystem (Stanford University, March 2020). PAC-MAN can theoretically find and destroy viruses in vitro, however, it has not been tested on the actual SARS-CoV2 virus. It needs further development and clinical trials. It could be used prophylactically as well as therapeutically. Also, it can be used as a reliable real-time option for taxonomic classification of novel pathogens.
- Program for Monitoring Emerging Diseases (ProMED). This is a program of the International Society for Infectious Diseases (ISID). It was launched in 1994 as an Internet service "to identify unusual health events related to emerging and re-emerging infectious diseases and toxins affecting humans, animals, and plants". It is the largest publicly-available system conducting global reporting of infectious diseases outbreaks. It produces reports and commentaries provided by a multidisciplinary global team of (SME) moderators in 50 subject matters in various fields including virology, parasitology, epidemiology, entomology, and veterinary and plant diseases. Located across 34 countries, it constantly scans for, reviews, and posts information related to global security (human, animal, and plant health) security. ProMED is an important and longstanding contributor to the global emerging and re-emerging infectious disease surveillance landscape. Over the last 25 years, it has been the first to report on numerous major and minor disease outbreaks including SARS, MERS, Ebola, the early spread of Zika, and many others.
- InfectControl 2020 program (Germany). It seeks to develop strategies for prevention, early recognition, and control of infectious diseases. It aims to detect infections without molecular-biological methods during passenger screening.
- Surveillance and mapping. Monitoring people who are exposed to animals in viral hotspots (including via virus monitoring stations) can register viruses at the moment they enter human populations - this might enable prevention of pandemics. The "Surveillance, Outbreak Response Management and Analysis System" (SORMAS) (of Germany, The Netherlands,

and Nigeria) gathers and analyzes data during an outbreak, detects potential threats, and allows to initiate protective measures early.

In addition, we need screening blood samples from wildlife for new viruses and testing and containment systems for novel viruses.

Databases Needed to Assist Enabling Technologies

To assist enabling technologies, databases are needed. It is already clear that sequencing hubs should be made a permanent part of pandemic preparedness, prevention, and eradication. Sharing of pandemic genome data openly and widely will help analyze how viral variants are spreading around the world. Approximately 50 tracking databases have sprung worldwide to evaluate several of the measures discussed in my book. Their aim is to assess the efficacy of any number of such measures in containing the pandemic. Examples of databases are provided in Appendix 2.

Existing Vaccines and Therapeutics Programs

To detect emerging variants, at least 5% of all cases (or 23,000 sequences) would be needed. We must ramp up surveillance of SARS-CoV2 to detect variants, otherwise vaccines will be less effective and may spread undetected to other countries and regions, particularly those hardest hit by the disease. The future of SARS-CoV2 will also depend on whether it establishes itself in a wild animal population. Again, historically, several diseases brought under control (yellow fever, Ebola, chikungunya) continue to persist because animal reservoirs provide opportunities for the pathogens to spill back into people. While it likely originated in bats, SARS-CoV2 may infect many animals including cats, rabbits, hamsters, and minks from which it could spill back into people.

Some climate scientists have also argued that small climate changes can result in substantial outbreaks when the seasons change, if control measures are inadequate. Over time, seasonal effects could play a more important part in driving infection trends as more people build up immunity. They have also recommended investing in pan-virus vaccines for pandemic preparedness.

The following programs are noted:

- Designing a globally-coordinated vaccine surveillance system for the purpose of monitoring vaccine changes predicated on new SARS-CoV2 virus variants to inform and advise national authorities and vaccine companies.
- U.S. National Institutes of Health (NIH) backed the project “Antiviral Drug Discovery and Development Center (AD3C)”. Launched in 2014, it was tasked to inventory candidates from drug libraries that could inhibit viruses such as influenza, coronaviruses, alpha-viruses (such as those responsible for chikungunya), and flaviviruses (the pathogens behind dengue and Zika among others). It is also planning a major program to develop therapeutics against SARS-CoV2 variants and other viruses with pandemic potential.
- COVID R&D Alliance (CRDA), a consortium of more than 20 life science companies and venture-capital firms from around the world. It aims to create an organization that will accelerate the development of drugs against coronaviruses. It has identified 25 candidate medicines for trials in humans perhaps in time for when the next pandemic strikes.
- Public health requires investments in drugs to counter any pathogen with epidemic or pandemic potential. The work done due to the funding provided for COVID-19 should be of help for the next pandemics if we have not by then devised ways to prepare, predict, and prevent them. The world cannot afford to be caught again empty-handed with empty medicine cabinets.
- To protect people and wildlife from each other, vaccination in biodiversity would be needed. Interactions of people with wildlife are more frequent in rural areas of low-to-middle income countries. Such areas host most biodiversity hotspots and have less access to vaccines than do urban centers. Vaccinating the often-neglected people in these areas should at the same time reduce the risk of secondary reservoirs of infection from people to wildlife with the potential of reinfection of humans with new variants. This would have the added benefit of protecting wildlife and limiting the 'reverse spillover',

as has happened earlier for various human respiratory viruses in wild great apes in South Africa.
- A new industry-backed coalition is taking aim at influenza viruses and coronaviruses.

Some other groups hope to create antivirals for more distantly-related pathogens that pose a pandemic risk. Like in the successful development of COVID-19 vaccines, it is hoped that, similar ventures between governments and pharmaceutical companies could likewise develop effective antiviral drugs. Nonetheless, with pharmaceutical companies fixated on HIV and hepatitis-C, it will be hard to co-opt them for fighting known or imagined threats.

New Vistas in Pandemic Research

Research is essential for understanding how pathogens spread and cause disease, and to generate safety and efficacy data to support regulatory decisions on clearance, approval, licensure, and emergency use. Recent outbreaks of diseases such as Lassa fever, Ebola, Zika, and Nipah have highlighted gaps in the knowledge base needed to optimally stem the outbreak. These gaps can be addressed through the integration of infectious disease research into global preparedness and response activities. Research during an emergency response is often the only available and most effective opportunity for determining the safety and efficacy of a vaccine, therapeutic, or diagnostic (which may expedite licensure and access to safe and effective countermeasures).

Since 2015, global institutions such as the WHO and the World Bank (WB), and public-private partnerships, have been responding to deficiencies in research by ensuring the integration of research into global health security preparedness and response efforts.

Further, in the area of epidemiological simulation, it would be necessary to conduct retrospective analyses to assess the actual performance of the models and inform on updating them and their simulations. The codes, models, data, and results should also be open and made available to many.

Priorities should also be allocated to research relevant to countries with weaker surveillance, laboratory facilities, and health systems, vaccine manufacturing and supply routes, and diagnostics that should be available at the point of care.

Together with the GVP and the GHVP, and with due consideration of the identified 10 cardinal socio-ecological factors, the new paradigm of "one world-one ecohealth" may have the potential to be the beginning of the end of pandemics.

Conclusions

The following conclusions can be drawn regarding the current state of global health:

- COVID-19 has evidenced the current poor state of global health. Ten intertwined cardinal socio-ecological factors that are the root causes of pandemics have been identified. These need to be simultaneously tackled and remedied. Some of these factors could be correlated with the United Nations Sustainable Development Goals. Within this endeavor, the Human Global Virome Project may be of critical importance.

- A blueprint has been offered for a 6-level strategic pandemic prevention and prevention. The value and success of the proposed approach will be gauged by four identified measures. Within that blueprint, a stage could be reached wherein future pandemics could be predicted and prevented.

- A new International Pandemic Treaty was advocated and some of its particulars were discussed. This would be in addition to current international laws, programs, and agreements that may also help in the creation of the World Environmental Organization. Such an organization may overcome the difficult collaborations between the numerous international, intergovernmental, regional, and national organizations, which do not work well together.

- The current "One World" paradigm should evolve to the new paradigm "One World-One Health", or better yet "One World-One ecoHealth".

- Taking advantage of several existing enabling

technologies and international/national databases, pandemics could be modeled according to two general types (epidemiological; climate/ weather prediction). Such modeling has and could continue to assist in making policy decisions regarding the management of pandemics. In the meantime, existing programs regarding vaccines and therapeutics and research should be continued.

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