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POLICY ARTICLE

Challenges and Opportunities in COVID 19: A comprehensive concise review and proposal

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ABSTRACT

This paper first offers complexity theory as an overarching theoretical framework to conceptualize both the current COVID 19 pandemic and then a series of related topics that lead to a focused recommendation for prevention and management of inevitable future pandemics. The deployment of streaming wireless sentinel surveillance is advocated, suggesting the use of AI- assisted algorithmic processing of psychophysiological data to identify emerging pathogens of potential concern and implement evidence based preventive and intervention strategies. Data are collected using existing personal devices which are both effective and scalable in both developed and developing locations.

Introduction:

"March 11, 2020: Along with December 7, 1941 and September 11, 2001, it was a day when America and the world changed" according to the Foreign Policy Association[1]. That date marked the WHO's declaration of the novel coronavirus as a global pandemic. WHO Director Gehbreyes stated "we are deeply concerned both by the alarming levels of spread and severity and by the alarming levels of inaction" He forcefully called on all nations to "take action now to contain the virus. We should double down," he continued. "We should be more aggressive." While accurate, this sentiment was also likely tardy. Reports of the unfolding pandemic had already been circulating in the scientific community for months. Yet many healthcare systems remained grossly unprepared despite credible, repeated warnings.

Some national governments were uncooperative and downplayed or denied the significance of the looming pandemic crisis. This attitude was perhaps exemplified most clearly by then-President Donald Trump's statement that the pandemic was a "hoax"–and would not affect the US - this despite multiple briefings alerting him that the threat was both very real and very dangerous [2]. He erroneously declared that the US was the "best prepared country", ignoring the input of epidemiologists and other specialists that the world was seriously unprepared for such a predictable occurrence. Countries that did not implement time honored or evidence-based preventive action suffered greatly. The US alone experienced over 103 million cases and 1,100,000 fatalities as of November 2023, the greatest total and highest per capita death toll of any country[3]. These deaths exceeded the number of total American fatalities due to the World Wars, Korea and Vietnam combined. This recent history is discouraging and dangerous, yet some positive developments can be celebrated: These include the emergence of effective COVID 19 vaccines, influence of Module 2 and the National Institute for Health and Care Excellence[4]. This decidedly mixed record makes it necessary to humbly acknowledge the limits of science; a humility which must stimulate the urgent necessity of deploying existing multidisciplinary evidence-based systems of knowledge.

This paper places the lamentable global response to the COVID 19 pandemic into scientific and sociocultural contexts, tracing both remarkable triumphs and serious deficiencies that transpired, as well as historically ignored recommendations and lessons, learned and unlearned. While attempting to be both comprehensive and yet concise, limitations of empirically verified intellectual resources create the boundary conditions for this article. However, a more detailed description of some salient challenges and opportunities follows, culminating in a focused recommendation.

Complexity Science and Complex Adaptive Systems:

Discrete disciplines such as immunology, virology, epidemiology and public health, cognitive and affective neuroscience, health psychology, as well as sociocultural issues are all salient in our understanding of pandemics. However, an overarching model is needed to weave together knowledge from disparate sources to promote a fuller understanding

required for the prediction of and intervention in complex phenomena. The transdisciplinary field of complexity science is such a model.

While growing rapidly, basic concepts such as complex adaptive systems, emergence, self-organization and exquisite sensitivity to initial conditions have been identified. A complex adaptive system is defined as a set of agents following a relatively small number of interaction rules that produce unexpected emergent complex behavior which frequently could not be predicted by analyzing the separate elements of the system. This process is reflected in the well known evolutionary maxim of survival of the fittest, with fitness being defined as adaptive ability and favoring the proliferation of increasingly adaptive entities. Rather than follow stereotypical "top-down", hierarchical patterns assumed to occur in typical cause and effect sequences as our current scientific worldview has favored, new and unique outcomes are said to emerge through self-organizing processes which have been shown to occur a large number of phenomena, ranging from atomic and cellular to social, global and even galactic activities. While such phenomena are often discounted as incomprehensible "chaos", scientists with a proclivity towards systems conceptualization[5-8] have shown many of these chaotic phenomena actually follow specific stochastic patterns being neither strictly deterministic nor totally random, but capable of probabilistic understanding.

For example, it has been historically thought to be impossible to understand and predict weather. The work of Edward Lorentz[9] of the University of Washington has shown, however, the principle of sensitivity to initial conditions explains otherwise inexplicable patterns in developing weather systems. Many of these challenging phenomena are "bottom up" in their unfolding and demonstrate self-organization into various attractor basins, including the bi-phasic Butterfly Attractor, first observed by Lorentz. Water's perennially observed transition from solid to liquid to gas is an example of significant phase change.The fractal nature of much self-organization was meaningfully explored by the mathematician Benoit Mandelbrot, and definitive illuminations of non-linear systems have been provided by Steven Strogatz in both scientific and popular venues.

The traditional "top down" command and control trope has been assumed to be necessary and effective, but experience has shown it to be frequently ineffective and sometimes disastrous. The US military has codified this in its West Point training directive to field commanders: "All battle plans prove inadequate to conditions on the ground". This warning applies equally to participants in any hierarchical bureaucratic organization.

The evolutionary significance of adaptation has been associated with the emergence of resilience at many levels. The importance of digital technology and network dynamics has been a major contributor to our ability to observe and understand complex phenomena. A recent New England Journal of Medicine[10] editorial notes the explanatory value of complex systems analysis as an expansion of traditional scientific medical models. The complex systems model also may facilitate the fleshing out of the development of what has been variously termed One Health, Personalized or Precision Health, Medicine 3.0, i4P Health and Deep

Health [11], since by its ecological nature, it emphasizes the embedded and interactive aspect of phenomena.

Epidemiology:

Of the many health disciplines relevant to our understanding of pandemics, epidemiology is perhaps the most often identified field which has historically addressed population health. Generally defined as the study of disease within populations, William Foege, one of the most prominent contributors to the field, notes that epidemiology actually has two pillars, one scientific, emphasizing evidence-based knowledge and one philosophical, emphasizing social justice. The field emerged as a distinct branch of medicine based on astute observations such as John Snow's noting in 1854 that many cholera cases came from a London neighborhood served by the Broad Street pump. When the pump handle was removed, the case incidence fell rapidly, despite the ignorance of the germ theory of disease. His use of a map of London to indicate case fatalities was a major step forward in a more scientific approach which was imminently actionable. Improved scientific techniques and methods made the field more robust and promoted a fuller understanding of major events such as the 1918 so-called Spanish Flu and the SARS and MERS outbreaks. Methods such as randomized controlled study designs, genetic/epigenetic interaction methods, and cross sectional and single subject experimental designs reinforced the efficacy of the field. At the same time, the interactive role of climate change, population growth, mass global transportation, poverty, supply chain dependency, industrial food production methods and increased human/animal interactions favoring zoonotic disease transmission illustrate the complexity of factors impacting the epidemiological landscape.

Using these concepts, tools and techniques will further facilitate what Michael Osterholm, Director of the University of Minnesota's Center for Infectious Disease Research and Policy has called "consequential epidemiology", the dissemination and application of epidemiological knowledge that has significant impact on public health and welfare, broadly defined. He has identified a number of "pandemic weaknesses" which have limited such consequential application. These include: politicization of public health, understaffed and equipped healthcare workforce, poorly coordinated healthcare systems, vaccine inequity and a growing hostility towards medicine and science in general. He has urged the development of "a new paradigm to *scare the wits into people,* since evidence, knowledge and logic are not enough". To most effectively bring this about, the disciplines of cognitive and affective sociobehavioral science, amongst others must be enlisted. This includes the study of cognitive biases[12], persuasive communication1[13], attachment processes[14], and self-domestication[15], to name only a few good candidates. Although the term Non Medical Intervention has been developed to refer to effective behaviors such as masking, social distancing, quarantine and mandatory vaccination, their value and the difficulty in implementing them has not been widely appreciated.

Ecological and evolutionary science have identified both indicator and key species as valuable concepts revealing both the health and potential survival of ecosystems which

may be productively integrated into our understanding and management of pandemics. These are only some of the disciplines that can make a more robust and sophisticated model of health and disease. The use of psychological science and other "non medical" disciplines has been called "epistemic trespassing"[16] by some, which could occur if knowledge from one domain is misapplied in another. More often this is a manifestation of the siloing that occurs between many scientific and other fields of knowledge, often to the disadvantage of the larger population. Reducing or eliminating such siloing is one of the major benefits of the application of complexity science.

One epidemiological activity which needs to be expanded is the use of sentinel surveillance. Various modes of observation and monitoring can indicate the early emergence of known or novel pathogens. Studies using social media data such as that produced using Google inquiries regarding influenza symptoms and wastewater samples have been shown to imperfectly indicate the presence of known pathogens. A less explored but potentially more impactful approach is the use of wireless remote monitoring of variables associated with disease and wellness. By harnessing existing internet and personal device infrastructure and hardware, this approach can be scaled to provide early warning of pathogen emergence to facilitate prompt analysis and containment if necessary.

In the arena of traditional national defense, a similar approach was used under the rubric of the Distant Early Warning System, using radar arrays that could identify aircraft or missiles that might be mounting an attack on the US. While the system was quite sensitive, it also made some misidentifications such as flocks of geese (false positives) but overall gave an improved level of awareness of possible attack. As has been mentioned earlier, pandemics have inflicted greater levels of mortality, morbidity and unmeasured social and economic costs than many of the recent US wars. As a consequence pandemic threats should be legitimately identified as a major national security focus, deserving of levels of funding sufficient for both preventive and interventive public health activities. Most Americans don't forget military threats to their nation. An effective "early warning system" would help guarantee that populations would suffer less from recurrent pandemic amnesia that only sets the stage for future public health disasters.

Heart Rate Variability:

Of existing technologies that can most readily be applied to sentinel surveillance, heart rate variability(HRV) is a robust candidate. This psychophysiological variable has been identified as a sensitive indicator of physical and psychological health and well being and a wide variety of diseases [17,18]. HRV was cited by Topol[11] as one of the important variables to be included in his thoughtful proposed *Deep Medicine*. Defined as the variation that occurs between successive heart beats, there are a number of useful statistics for deriving HRV including those in the time domain, the frequency domain and non-linear measures. While originally used for the noninvasive detection of fetal distress and presymptomatic sepsis, over ten thousand peer reviewed studies have explored its utility in applications

ranging from improving decision making regarding when to use emergency air evacuation in automobile accidents to assessment of executive CNS functioning. Several studies[19] have shown it to be a sensitive indicator of COVID 19 up to 9 days before the individual becomes symptomatic or even tests positive for the virus. As noted in the reviews cited above, HRV can be measured from a variety of personal devices such as belts, watches and rings, and implantables using some medical devices. The data obtained can be transferred wirelessly to applications using algorithms which produce health relevant data. Many of these devices also acquire other important data which could add value, including temperature, respiration rate, blood oxygen saturation and activity level. This of course would allow for the longitudinal realtime collection of a vastly enhanced digital vital sign suite, ideal for the early detection of decreased health status needed in sentinel surveillance. Such an approach can also be used in clinical medicine, health maintenance and performance optimization.

Artificial Intelligence:

As noted by Topol[11], collection of real time longitudinal psychophysiological data from a large population sample creates a huge dataset which benefits from a Big Data approach to understanding. The most relevant approach to developing a functional algorithmic sentinel surveillance system is the subset of artificial intelligence techniques called machine learning, applied as recurrent neural networks and convolutional neural networks, as well as the use of time series analysis and feature extraction, for example using Isomap. Such an approach would, as much as possible, take a multivariate approach, including not only HRV, but the augmented suite of variables mentioned above as input variables and COVID 19 status as output predictions. Because this approach has high sensitivity but less specificity, it would be ideal for investigating not only the rapidly evolving novel SARS-CoV-2 virus but other emerging pathogens, and could be integrated into whatever existing health system resources were present to manage outbreaks and triage functions. This concept of combined remote monitoring, personal device mediation and algorithmic AI-assisted analysis which has been sketched here has been explored in much greater detail [20-23]..

Socio-Cultural Economic and Political Factors:

Several socio-cultural trends also strongly impact our ability to intervene effectively before and during public health emergencies. "Pandemic

Amnesia", the tendency for a population and its leadership to decrease their interest, activities and funding regarding pandemic preparedness and intervention once a crisis has passed, has been perennial. Other factors are at play - not the least the inherent limitations on political action by officials habituated to focusing on current affairs. Another factor that limits our societal attention is the focus on short term outcomes such as quarterly corporate reports and stock market valuations. One of the most disheartening and damaging social pathologies is a widespread anti-intellectualism manifesting as anti-public health, anti-science and even

anti-expertise sentiment that has shown increasing impact on many nations. This is part of a disturbing spread of both misinformation and disinformation on a scale that prompted the coining by WHO of the term "infodemic" because of its increased frequency. A highly salient example was and continues to be the spreading of untrue or misleading information by former US President Trump, even when his close advisors apprised him of the huge danger of denying, ignoring or minimizing the COVID 19 pandemic. Peter Navarro, generally a strong Trump supporter and close advisor circulated a memo in January 2020, predicting great US mortality and morbidity due to the pandemic but this was ignored. The impact on the US both in terms of lives lost or limited and financial costs have been immense, representing a notable national security threat which has not been incorporated into the existing US National Security rubrik. Thus, both social and economic well being have been impacted with little public debate, furthering the process of "forgetting" the pandemic. While not due entirely to the actions or inactions of government, the COVID Crisis Group has described the US response to the pandemic as "collective national incompetence in governance"[24]. While this is a socio-cultural phenomena of vast scope and not amenable to a single focused scientific intervention, it is within the scope of the complexity science mandate to identify such factors and include them in policy determination.

A particularly distressing related socio-cultural issue identified by the Nobel Prize winning economist Angus Deaton are the dismal phenomena deemed "deaths of despair"[25], which include mortality due to opioid and other substance abuse, suicide and and related disease manifestations such as liver failure. Deaths are not the only metric, since high levels of social dysfunction are also implicated. Deaton suggests that it is conceptually fallacious to view these many disorders as strictly individual matters and criticizes his fellow economists who traditionally measure human well being in parochial economic terms, such as Gross Domestic Product. He urges a broadened view of human well being in his influential Nobel address.

Of course, there is danger in criticizing existing social mores. A poignant example is found in Henrik Ibsen's play "An Enemy of the People ''. Dr Stockman, the protagonist, became aware of a pathogen entering his community's main source of income, the local hot springs. When he brought this to light, he and his family were attacked personally, losing their jobs and home. It is ironic that Dr Anthony Fauci was similarly maligned by former-President Trump when he expressed science based opinions that displeased an ignorant and mendacious leadership. Notably, Dr. Fauci and his family experienced harrowing consequences beyond those of Dr. Stockman–he and his family received credible death threats and had government security personnel assigned to protect him and his family. Despite this or any other factors that would produce a Cassandra Effect of speaking the truth but fated to be ignored, the following recommendation is proffered.

Conclusion:

This paper has advocated a robust theoretical framework, that of complexity science. It has also traced various domains and aspects that should be considered in applying that framework to the understanding and intervention

in pandemics, such as the still-in-process COVID-19 pandemic. Of several applicable elements of epidemiology and public health reviewed, sentinel surveillance was identified as a particularly important aspect ripe for new application through the use of wireless psychophysiological monitoring and algorithmic analysis by several types of artificial intelligence.

In considering what recommendation would be productive, a brief recall of the history of the Manhattan Project and the US "Moonshot" is instructive. Both involved massive investment of scientific and financial resources, but the Manhattan Project's completion led one of its most visible scientific progenitors, Albert Einstein to renounce it and decry its consequences, which including a lengthy and expensive arms race and at least one moment of possible existential annihilation. John F. Kennedy's race to the moon was less contentious, although the launch of the Russian Sputnik satellite did engender an atmosphere of cold-war tension. Both projects required not only scientific endorsement but solid political leadership, since science without policy is anemic and policy without implementation power is pointless.

This recommendation is offered in the context of increasing global interdependence and an untenable imbalance of resource distribution. The viability of wireless biopsychological data acquisition has been demonstrated in many applications and the use of heart rate variability as a valuable indicator of disease, health and well-being has been strongly empirically supported. Additional physiological and behavioral variables should enhance its value. The use of personal devices, especially smartphones to acquire these data is widespread and growing rapidly worldwide. Artificial intelligence and network science are finding valuable applications daily, especially in the high priority area of meaningful predictive analysis schemes using neural network Deep Learning approaches[26.] Safeguarding the well-being of citizens and culture requires the following accountability mechanisms: Stringent privacy protections, citizen ownership of all data collected from them, with or without their consent, updated anti-trust laws, and algorithmic transparency requirements. It is proposed that an integrated sentinel surveillance system be strategically deployed to provide early warning of potentially lethal disease outbreaks in a relatively inexpensive but widely scalable public health monitoring approach guided by the provisos of complexity science. Like the proverbial canary in the coal mine, such a system would provide actionable information critical for investigation and outbreak management, serving a preventative function. Such a system will also demonstrate its potential applicability to health maintenance and promotion in both existing clinical medical settings and rapidly expanding innovative digital health activities. The wise words of Alan Turing apply: "We can only see a short distance ahead, but we can see much to be done".

Conflict of Interest:

None.

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Open Source Coding.

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