PANDEMICS
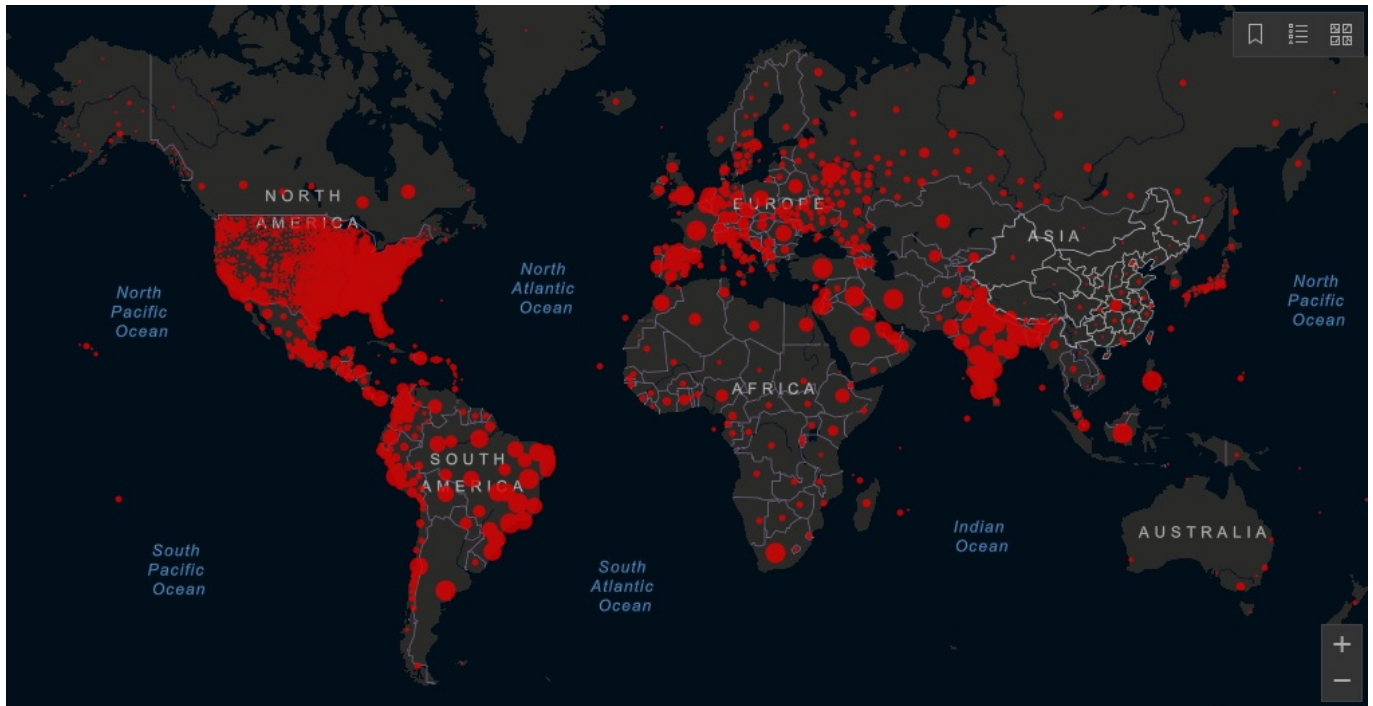

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OCTOBER 12, 2020

I. INTRODUCTION

In this essay, Nick Mascie-Taylor and Kazuhiko Moji explain the lessons learnt from the covid-19 pandemic include acting quickly, extensive testing, digital surveillance, public trust in government and leaders and cooperation between nations.

The essay may be downloaded in PDF format **here**

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Banner image: COVID-19 Dashboard by the Center for Systems Science and Engineering (CSSE) at Johns Hopkins University (JHU), accessed June 13, 2020, cases 37,738,569, deaths 1,078,868, **here**

II. NAPSNET SPECIAL REPORT BY C G NICHOLAS MASCIE-TAYLOR AND AND KASUHIKO MOJI

PANDEMICS

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Summary

A pandemic is defined as an epidemic occurring worldwide, or over a very wide area, crossing international boundaries and usually affecting a large number of people. Pandemics have occurred throughout human history and appear to be increasing because of rising emergence of viral diseases from animals (zoonoses). The risk of a pandemic arises from the combined effects of the Spark Risk (e.g. bushmeat hunting) and the Spread Risk (e.g. mode of transmission and population susceptibility). Pandemics have health, economic, gender, social and political impacts. Building pandemic preparedness is complex and requires considerable coordination. In the context of covid-19 modelling of transmission has been central to many government's response including introduction of lockdown and physical distancing. Developing vaccines for novel pathogens is not simple or straightforward and community mitigation measures are essential. There are a number of lessons which have been learnt from the covid-19 pandemic including acting quickly, extensive testing, digital surveillance, public trust in government and leaders and cooperation between nations.

Definitions - Epidemic, Endemic and Pandemic

When there is a rapid spread of a disease to many people in a population within a short period of time epidemiologists define this as an epidemic. Epidemics are mainly, but not entirely, due to infectious diseases. Infectious diseases are caused by pathogenic microorganisms, such as bacteria, viruses, parasites or fungi and the diseases can be spread, directly or indirectly, from one person to another. Zoonotic diseases are infectious diseases of animals that can cause disease when

transmitted to humans.

Epidemics of infectious disease are generally caused by a number of factors including a change in the ecology of the host population (e.g., an increase in the density of a vector species) or a genetic change in the pathogen making it more virulent, or the introduction of a new pathogen to a host population (by movement of the pathogen or the host). Generally, an epidemic occurs when host immunity to either an established pathogen or newly emerging novel pathogen is suddenly reduced or minimal. An epidemic may be restricted to one location; however, if it spreads to other countries or continents and affects a substantial number of people, it may be termed a pandemic. There is no universally agreed definition of when a disease outbreak should be called a pandemic, but three criteria generally need to be met (a) it needs to cause disease or death (b) there must be sustained transmission between people and (c) it must be spreading in multiple countries.

Pandemic and endemic should not be confused. In epidemiology an infection is said to be endemic in a population when that infection is constantly maintained at a baseline level within a geographic area. i.e. it is considered native to a defined population or geographical location.

History of Pandemics

Pandemics have occurred throughout history and appear to be rising in frequency, especially because of increasing emergence of viral disease from animals (zoonoses). The most quoted pandemic is Black Death which started in 1347 and was caused by the bacterium Yersinia pestis and resulted in between 75 and 200 million deaths in Eurasia and North Africa including about 30-50% of the European population. The Black Death most likely originated in central or eastern Asia from where it travelled along the Silk Road reaching Crimea by 1347. From there, it was most likely carried by fleas living on black rats that travelled on merchant ships, spreading throughout the Mediterranean Basin and reaching Africa, Western Asia, and the rest of Europe. Once it came onshore, the Black Death was in large part spread by human fleas leading to pneumonic plague.

In the twentieth century the Spanish flu also known as the 1918 influenza pandemic was the most severe pandemic in recent history. It was caused by a subtype of influenza A virus called H1N1 with genes of avian origin. The virus is called H1N1 because it contains the glycoproteins Haemagglutinin and Neuraminidase and the viruses are described as H1N1, H1N2 etc. depending on the type of H or N antigens they express. Although there is not universal consensus regarding where the virus originated, it spread worldwide during 1918-1919. In the United States, it was first identified in military personnel in April 1918. It is estimated that about 500 million people or one-third of the world's population became infected with this virus. The number of deaths was estimated to be at least 50 million worldwide. Most influenza outbreaks disproportionately kill the very young and the very old, with higher survival rates for those in between, but the 1918 pandemic had an unusually high mortality rate for young adults. Mass troop movements and living in close quarters during World War I caused the virus to spread and mutate faster, and the susceptibility of soldiers to the flu may have been increased by stress, malnutrition and chemical attacks. Improved transportation systems made it easier for soldiers, sailors and civilian travellers to spread the disease.

In February 1957, a new influenza A (H2N2) virus that originated in China, triggered a pandemic (Asian Flu) and killed at least a million people worldwide. The strain of virus that caused the pandemic was a recombination of avian influenza (probably from geese) and human influenza viruses. As it was a novel strain of the virus, the population had minimal immunity.

Making a vaccine for a new flu strain is very different from making a vaccine for something completely new like COVID-19, the novel coronavirus that emerged in 2019. Viable flu vaccines were

first developed in the 1940s, so creating a vaccine for the 1957 flu strain was not a case of 'starting from scratch'. When the new flu strain reached the United States in September 1957 the country was ready with a vaccine.

Influenza viruses are constantly changing. They can change in two different ways. (a) antigenic drift and (b) antigenic shift. Antigenic drift refers to small changes (or mutations) in the genes of influenza viruses that can lead to changes in the surface proteins of the virus: H (hemagglutinin) and N (neuraminidase). The H and N surface proteins of influenza viruses are "antigens," which means they are recognised by the immune system and can trigger an immune response, including production of antibodies that can block the infection. Influenza viruses that are closely related to each other usually have similar antigenic properties. So, antibodies in the immune system created against one influenza virus will very likely recognise and respond to antigenically similar influenza viruses (this is called "cross-protection").

Antigenic shift is an abrupt, major change in an influenza A virus, resulting in new H and/or new H and N proteins in influenza viruses that infect humans. Antigenic shift can lead to a new influenza A subtype in humans. One way an antigenic shift can happen is when an influenza virus from an animal population gains the ability to infect humans. Such animal-origin viruses can contain an H or H/N combination that is very different from the same subtype in humans such that most people do not have immunity to the new (e.g., novel) virus. The H2N2 influenza virus continued to transmit until 1968, when it transformed via antigenic shift into influenza A virus subtype H3N2, the cause of the 1968 influenza pandemic where 1 million people died worldwide. Another such antigenic shift occurred in the spring of 2009, when an H1N1 virus with genes from North American Swine, Eurasian Swine, humans and birds emerged to infect people and quickly spread, causing a pandemic (Swine Flu). When antigenic shift happens, most people have little or no immunity against the new virus.

The Human Immunodeficiency Viruses (HIV) are two species of Lentivirus (a subgroup of retrovirus) that infect humans. Over time, they cause Acquired Immunodeficiency Syndrome (AIDS) a condition in which there is progressive failure of the immune system allowing life-threatening opportunistic infections and cancers to develop. Both HIV viruses are believed to have originated in non-human primates in West-central Africa and transferred to humans (zoonosis) in the early 20th century. In most cases, HIV is a sexually transmitted infection and occurs by contact with or transfer of blood, pre-ejaculate, semen and vaginal fluids. Non-sexual transmission can occur from an infected mother to her infant during pregnancy, during childbirth by exposure to her blood or vaginal fluid, and through breast milk. Within these bodily fluids, HIV is present as both free virus particles and virus within infected immune cells.

AIDS was first clinically observed in 1981 in the United States. The initial cases were injection drug users and gay men with no known cause of impaired immunity. The earliest retrospectively described case of AIDS is believed to have been in Norway in 1966. Worldwide it is estimated that over 70 million people have been infected and about 39 million deaths. The control of HIV/AIDS normally includes the use of multiple antiretroviral drugs. In many parts of the world, HIV has become a chronic condition in which progression to AIDS is increasingly rare

The Zika virus was first isolated in 1947, in a rhesus monkey from a forest near Entebbe, Uganda. In early 2015, a widespread epidemic of Zika fever, caused by the Zika virus started in Brazil and spread to other parts of South and North America as well as to several islands in the Pacific and Southeast Asia. The virus is spread mainly by the Aedes aegypti mosquito, which is commonly found throughout the tropical and subtropical Americas. It can also be spread by the Aedes albopictus (Asian tiger) mosquito, which is distributed as far north as the Great Lakes region in North America. People infected with Zika can transmit the virus to their sexual partners. Prior to this outbreak, Zika

was considered a mild infection, as most Zika virus infections are asymptomatic, making it difficult to determine precise estimates of the number of cases.

Since 2000 other epidemics/pandemics have included SARS (Severe Acute Respiratory Syndrome). SARS is caused by a coronavirus and is thought to be an animal virus from an as-yet-uncertain animal reservoir, perhaps bats, that spread to other animals (civet cats) and first infected humans in southern China in 2002. The SARS epidemic affected 26 countries and resulted in more than 8000 cases in 2003. Since then, a small number of cases have occurred as a result of laboratory accidents or, possibly, through animal-to-human transmission.

Coronaviruses are a large family of viruses that are known to cause illness ranging from the common cold to more severe diseases such as Severe Acute Respiratory Syndrome (SARS). COVID-19 is an infectious disease caused by a newly discovered coronavirus. Most people infected with the COVID-19 virus experience mild to moderate respiratory illness and recover without requiring special treatment. Older people, and those with underlying medical problems like cardiovascular disease, diabetes, chronic respiratory disease, and cancer are more likely to develop serious illness or death. The COVID-19 virus spreads primarily through droplets of saliva or discharge from the nose when an infected person coughs or sneezes. Currently there are no specific vaccines or treatments for COVID-19. However, there are many ongoing clinical trials evaluating potential treatments. As of October 7th, 2020, there have been nearly 36 million confirmed cases worldwide and over 1,000,000 deaths. The worst affected countries are the United States (over 7.5 million cases), India (nearly 6.8 million cases) and Brazil (nearly 5 million cases).

Origins of Pandemics

Most new pandemics originate from zoonotic transmissions of a pathogen from animals to humans. Zoonoses can enter human populations from both domesticated animals (e.g. poultry) and wildlife. In the past significant zoonoses were introduced as a result of increased human-animal interaction following domestication but also from livestock production systems. Some pathogens, including Ebola, have entered humans through hunting and consumption of wild species such as bushmeat, the wild animal trade and other contacts with wildlife. Most zoonotic pathogens are not well-adapted to humans, however those that are sufficiently adapted to humans to enable transmission between humans, directly or indirectly, frees constraints of habitat range of an animal reservoir and enables geographic spread.

Pandemic risk factors

The risk of a pandemic arises from the combined effects of (a) the Spark Risk and (b) the Spread Risk. A zoonotic spark risk could arise from the introduction of a pathogen from either domesticated animals or wildlife sources. Zoonoses from domesticated animals are more likely where dense livestock production (intensive and extensive farming and live animal markets) occurs including areas of China, India, Japan, the United States and Western Europe. Wildlife zoonosis risk is geographically distributed more widely in China, India, West and Central Africa and the Amazon Basin. Risk drivers include bushmeat hunting, use of animal-based traditional medicines and the extension of roads into wildlife habitats.

On January 30, 2020, WHO declared a Public Health Emergency of International Concern, a month after COVID-19 was identified in Wuhan, China. At this point, several mathematical and computational models had already raised the alarm about the potential of COVID-19 to cause a global pandemic and the dire consequences for public health should drastic action not be taken.

During the emergence of a novel pandemic, predictive modelling is important in public health

planning and response. However deriving insights with predictive modelling requires diverse datasets, which are often imperfect, particularly in the crucial period of epidemic emergence when surveillance is imprecise, and little is known about the epidemiology or the clinical features of the disease.

In the case of Wuhan, the analyses suggested that substantially more cases were present in Wuhan than were reported in the official statistics. The predictive models showed that the cordon sanitaire around Wuhan reduced the growth rate of exported cases, but it came too late to prevent national and international spread. Control of the epidemic in countries outside China failed because of the difficulty in detecting and isolating infected travellers.

A predictive model provided the first evidence for the hypothesis, now widely accepted, that pre-symptomatic and asymptomatic infected individuals fuelled local epidemics. Consequently, the majority of imported cases went undetected, generating extensive chains of local transmission.

There has been extensive modelling of the transmission of covid-19. The outcomes from the models can be quite heterogeneous depending on whether a random event or clustering is assumed. Another issue is whether the models are used to plan for health system capacity (i.e. ICUs) or for public health interventions. In very general terms, models which did not consider clusters including 'superspreaders' did not point to early targeted public health interventions. Models which assumed random distribution and focused on hospital capacity lead to broad lockdowns. As the pandemic progressed and lockdowns were implemented in many countries, analyses based on mobile phone records provided essential support to public health assessments across the different stages of lockdown implementation and release.

Consequences of Pandemics

Health Impacts

The direct health impacts of pandemics can be catastrophic as has been seen with the deaths due to HIV/AIDS exceeding 39 million while Black Death was thought to have wiped out 30-50% of the European population. Influenza pandemics have tended to affect younger and more economically active segments of the population as younger people have lower immunity than older people. For COVID-19 this does not seem to be the case and the mortality rate from COVID-19 is much higher in vulnerable groups particularly those with co-morbidities. More older people have co-morbidities, so people associated higher death rate with age, and this type of messaging led to young people thinking they were not vulnerable

The indirect health impacts of pandemics can increase morbidity and mortality further through diversion or depletion of resources to provide routine health care. During the 2009 influenza pandemic a greater surge in hospital admissions for influenza and pneumonia was associated with statistically significant increases in death attributable to acute myocardial infarction and stroke. The availability of health care workers usually decreases during a pandemic because (a) they are ill themselves (b) need to care for ill family members (c) need to care for children because of school closures (d) of fear-driven absenteeism or increased risk of death. In the case of COVID-19 health workers have reported serious shortages of Personal Protective Equipment (PPE) in nearly all the 63 countries and territories surveyed. In the UK, a survey of more than 16,000 doctors by the British Medical Association found that 48% of the respondents reported buying PPE for their own use or using donated PPE due to a lack of supplies at their workplaces. The survey also found that 65% of doctors said they felt either "partly or not at all protected".

Economic Impacts

Pandemics can cause acute, short-term fiscal shocks as well as longer-term damage to economic growth. Early-phase public health measures to contain or limit outbreaks entail significant human resources and staffing costs and as an outbreak grows, new facilities may need to be constructed (e.g. hospitals) to manage additional infectious cases along with additional demand for consumables (medical supplies, personal protective equipment and drugs).

A further economic impact is that tax revenues are likely to be diminished especially in Low- and Middle- Income countries. World Bank economic simulations indicate that a severe pandemic could reduce World Gross Domestic Product (GDP) by about 5%. The reduction in demand due to aversive behaviour (such as the avoidance of travel, restaurants and entertainment facilities) further damages the economy.

In the context of COVID-19, the pandemic has caused the largest recession in history, with up to a half of the global population at one time being placed on lockdown. Supply shortages have occurred in a number of sectors due to panic buying, increased use of goods to fight the pandemic, and disruption to factories. There have been widespread reports of shortages of pharmaceuticals and the technology industry, in particular, has been warning about delays to shipments of electronic goods. Possible instability generated by an outbreak and associated behavioural changes could result in price spikes, and disruption to markets. Such price rises would be felt most by vulnerable populations who depend on markets for their food as well as those already depending on humanitarian assistance to maintain their livelihoods and food access.

Gender, social and political impacts

When crises strike, women and girls are harder hit by economic impacts than men. Around the world, women generally earn less and save less, are the majority of single-parent households and disproportionately hold more insecure jobs in the informal economy or service sector with less access to social protections. This leaves them less able to absorb the economic shocks than men. For many families, school closures and social distancing measures have increased the unpaid care and domestic load of women at home, making them less able to take on, or balance, paid work. The situation is worse in developing economies, where a larger share of people are employed in the informal economy in which there are far fewer social protections for health insurance, paid sick leave and more. Although globally informal employment is a greater source of employment for men (63%) than for women (58%), in low and lower-middle income countries a higher proportion of women are in informal employment than men. In Sub-Saharan Africa, for example, around 92% of employed women are in informal employment compared to 86% of men.

In the context of COVID-19 it is likely that the pandemic could result in a prolonged fall in women's incomes and labour force participation. The ILO estimates global unemployment will rise to between 5.3 million ("low" scenario) and 24.7 million ("high" scenario) from a base level of 188 million in 2019 as a result of COVID-19's impact on global GDP growth. In the U.S.A. men's unemployment went up from 3.55 million in February to 11 million in April in 2020 while women's unemployment – which was lower than men before the crisis – went up from 2.7 million to 11.5 million over the same period. The picture is even bleaker for young women and men aged 16–19 in the U.S.A., whose unemployment rate jumped from 11.5 per cent in February to 32.2 per cent in April 2020.

Large scale outbreaks of infectious disease have direct and consequential impacts. For example, widespread public panic during disease outbreaks can lead to rapid population migration and migrants face increased health risks arising from poor sanitation, poor nutrition and other stressors. Migration also increases the risk of further spreading an outbreak.

There have also been political casualties as a result of COVID-19. In the USA President Trump has

put the economy as his priority and many states had lifted lockdown by the end of May 2020. Lifting lockdown occurred despite infections increasing and the country ranks as the worst affected in the world. The human toll of the pandemic in the USA, combined with disastrous press briefings and other factors (termination of USA relationship with WHO and response to Black Lives Matter) has led a slump in Trump's popularity. In Brazil President Jair Bolsonaro has seen a nosedive in his popularity because of his failure to acknowledge the seriousness of the pandemic. In both Japan and the UK, the Prime Ministers, Shinzō Abe and Boris Johnson, respectively have seen their popularity decline because of their handling of COVID-19.

Pandemic preparedness and response

The COVID-19 pandemic that was declared on 11 March 2020 has affected countries on all continents. The reported case numbers are certainly underestimates given the shortages or unavailability of test kits in many countries, a virus with a basic reproductive value (R0) of 2.2, and evidence of viral shedding from asymptomatic infected people. In addition to suspending travel and efforts to reduce crowds, countries are taking unprecedented measures, including wartime strategies to enhance production of medical supplies in the US, the use of the national guard to restrict movement of people, and suspension of exports of medical products from certain countries (e.g., Saudi Arabia, India).

Community Mitigation

As no specific drugs or vaccines are available currently, and health systems are overburdened everywhere then countries are relying on targeted, non-coercive, community interventions with sufficient transparency and public engagement and trust. Such measures may help delay the exponential spread of the outbreak until drugs become available.Community mitigation measures are actions taken to slow the spread of infectious diseases. The goals for using mitigation strategies in countries that are experiencing community transmission of COVID-19 are to decrease virus transmission overall and, in particular, protect:-

(a)   Individuals at increased risk for severe illness, including older adults (65+ years)

(b)   People of any age with serious underlying medical conditions (e.g. chronic lung disease, immunocompromising conditions, diabetes)

(c)   Vulnerable populations (e.g. refugees, internally displaced persons, prisoners) and

(d)   First responders – healthcare personnel and critical infrastructure workers

The key community mitigation strategies being used are:-

(a)   Cancellation of ad hoc events and suspension of events with super spreader potential

(b)   Use of social distancing measures to reduce direct and close contact between people in the community; more recently use of face masks in shops has been made obligatory in many countries

(c)   Travel restrictions, including reduced flights and public transport and route restrictions without compromising essential services

(d)   Voluntary home quarantine of members of household contacts and for people returning from countries with elevated COCID-19 reported cases e.g. the UK government recently introduced in July and August 2020 14-day quarantine for all people returning from a number of countries including France and Croatia

(e)   In some countries changes to funeral services to minimise crowd size and exposure to body fluids of the diseased

(f)   Clear communication from national and international health authorities to ensure verified information and avoid fake news, rumours, and panic

Even when the R0 is low, the crowd density during mass gatherings predisposes to high rates of transmission. On 27 February 2020 Saudi Arabia suspended the year round Umrah pilgrimage, and the transmission of COVID-19 in the country has been low. This contrasts with Iran, which did not intervene in the religious pilgrimage in Qom and has seen large regional outbreaks. Other potential mass gatherings -including the 2020 Olympic Games, Dubai Expo 2020, and Hajj pilgrimage have either been delayed or cancelled.

Social distancing measures - decreasing the frequency and duration of social contacts among people of all ages - reduces the person-to-person transmission of the virus. The closure of schools and universities, childcare facilities, religious services, entertainment venues, and other places where people congregate is an important such measure. Schools and day care centres represent the most socially dense environment (3-5 m2/child) compared with offices (18 m2/person) or homes (36-44 m2/person).Although current data do not indicate that children are especially susceptible to COVID-19, adults who interact in school settings are at risk, and children with underlying conditions or those living in areas with high disease transmission rates may be carriers. School closures cannot be implemented without workplace level interventions, distance and remote learning, and school meal options for children in need. Office space is another enabling environment for respiratory disease transmission. New shift work and rotation schedules seeking to decrease social density can minimise disease propagation. Telemedicine, video conferencing, telecommuting, and expanded leave policies may help staff adhere to social distancing policies.

Travel is the single most important contributor to disease transmission. Absolute travel bans may increase fear and affect the travel of essential staff and the timely movement of supplies. Home deliveries of essential commodities are feasible in some communities. Reduced frequency of transport (e.g. flights, trains) and route restrictions have been imposed, along with community sensitisation, aiming to reduce the demand for travel. Institutional quarantining of people who have been in contact with confirmed or probable cases is unrealistic during pandemics as it overwhelms the system and may lead to more infections. Voluntary home quarantine reduces stress on the healthcare system. Although family clusters of infections may occur, the numbers of affected people are likely to be far lower than in institutional settings. There has been very substantial increase in use of telehealth, from providing counselling to checking on patients with chronic conditions, to mobile apps for self care. In many countries and some communities, funerals are conducted in the homes of those who died; this was a key determinant of the Ebola outbreak. Given the role of body fluids in viral transmission, and because of crowding during funerals in some settings, new guidelines on funerals have been put in place.

Genetics of COVID-19 and vaccine development

Currently, there are six strains of coronavirus. The original one is the L strain, that appeared in Wuhan in December 2019. Its first mutation, the S strain, appeared at the beginning of 2020, while, since mid-January 2020, 2 further strains, V and G have appeared. To date strain G is the most widespread, it mutated into strains GR and GH at the end of February 2020.

Strain G and its related strains GR and GH are by far the most widespread, representing 74% of all gene sequences analysed. Strains G and GR are the most frequent across Europe and Italy. According to the available data, GH strain seems close to non-existence in Italy, while it occurs more

frequently in France and Germany. This seems to confirm the effectiveness of last months' containment methods.

In North America, the most widespread strain is GH, while in South America the GR strain is more frequent. In Asia, where the Wuhan L strain initially appeared, the spread of strains G, GH and GR is increasing. These strains landed in Asia only at the beginning of March, more than a month after their spread in Europe. Globally, strains G, GH and GR are constantly increasing. Strain S can be found in some restricted areas in the US and Spain. The L and V strains are gradually disappearing.

Historically, it has taken years to show that vaccines are both safe and effective and 90% of all vaccines that start clinical trials never make it to the end, either because they're not eliciting an effective immune response or there's some safety concern and they drop out.

172 economies are now engaged in discussions to potentially participate in COVAX, a global initiative aimed at working with vaccine manufacturers to provide countries worldwide with equitable access to safe and effective vaccines, once they are licensed and approved. COVAX currently has the world's largest and most diverse COVID-19 vaccine portfolio - including nine candidate vaccines, with a further nine under evaluation and conversations underway with other mayor producers. There are concerns that the immune protection from the COVID-19 virus may not last very long as a man from Hong Kong in July 2020 was found to be re-infected four and a half months after the patient originally caught the virus.

Some lessons learnt from COVID-19 which will help in future pandemics

(a)   Move/act quickly - had China implemented widespread testing, a cordon sanitaire around Hubei and other measures a week earlier, it would have reduced China's caseload by 66% while acting three weeks earlier would have cut cases by 95%.

(b)   It is known what works to contain the virus - the countries that implemented early and had extensive testing, such as South Korea and Iceland, have been able to keep their societies relatively open, without losing the virus into their populations.

(c)   Implementation is less than straightforward - this outbreak has demonstrated that a country can have the best laboratories in the world, the best notification systems and software, but without the appropriate governance of when to use these powers the number of COVID-19 cases increase.

(d)   Digital surveillance - civil liberties tested - digital surveillance tools that might have been closely scrutinised in normal times have been urgently rolled out over recent weeks. More than 40 countries have implemented some form of surveillance or censorship in the name of fighting the coronavirus. The potential for abuse is high - what is justified during an emergency now may become normalised once the crisis has passed.

(e)   Public trust is a government's most valuable asset - there is no precedent for up to half of the world's population living under some kind of lockdown. It might just be the single largest collective act undertaken by humanity. Over the next months, governments are going to allow people to resume their working lives amid the worst economic conditions since the Great Depression. Should new waves of the virus be detected, states may again ask their citizens to return lockdown. Managing this is going to require significant public trust, that in some places are quickly eroding

(f)   Leaders who deny science are a liability - many leaders have enjoyed what may be a temporary surge in popularity as frightened citizens rally around them in a crisis. Two notable exceptions have been the US president, Donald Trump, and his Brazilian counterpart, Jair Bolsonaro, whose ratings

have declined sharply.

(g)   Self-sufficiency matters - governments will not forget the global scramble to obtain for personal protective equipment and medical supplies during the last few months. Several countries have already restricted the exporting of some pharmaceuticals and more than a dozen countries have imposed bans on selling some food abroad.

(h)   The world cannot beat the virus without cooperating - the lack of cooperation has weakened the world's response. A global stimulus package might have prevented the economic catastrophe unfolding in many countries. Coordinated shutdowns and reopenings would have slowed the spread of the virus and could speed up the recovery. The COVAX initiative is to be welcomed as it demonstrates cooperation between governments, researchers, manufacturers and multilateral partners. By pooling resources and acting in solidarity the vaccine once created will be available equitably to all countries.

(i)   Austerity and inequality make for less resilient - no economy could withstand the shock of a large slice of the workforce ordered to stay at home. The problems with tying health insurance to employment in the U.S.A. have become even more obvious: the 26 million Americans who have filed for benefits over the past month did not just lose their jobs, many also lost their medical coverage.

(j)   Increased burden for the poor, ethnic minorities and migrants - insecure work and barriers to healthcare disproportionately burden people from ethnic minorities, migrants and poor people: both are dying from COVID-19 at a higher rate in the USA and Britain.

(k)   Good governance is also very important - countries with lower number of cases and deaths also had less of a decline in their economy.

COVID-19 interventions have focused on stopping viral transmission and controlling the spread of the pathogen. Actions by Governments have been driven mainly by epidemic modellers and infectious disease specialists. However, two categories of disease are interacting, - infection with COVID-19 and an array of non-communicable diseases (NCDs).   Consequently COVID-19 can be thought of as a syndemic not a pandemic. The notion of a syndemic was first conceived by Merill Singer in the 1990s. He argued that a syndemic approach reveals biological and social interactions that are important for prognosis, treatment and health policy. Limiting the harm caused by COVID-19 will require far greater attention to NCDs and socio-economic inequality.

This COVID-19 pandemic is not the worst in human history and the morbidity and mortality of young children, adolescents and young adults appears to be low. If a virus mutation occurs and the mortality of young people increases, then the pandemic will become much more widespread and serious. To reduce the risk of such a mutation the pandemic must be controlled as much as possible. In this sense, the strategy of the US and Brazil is incorrect, based on the Darwinian (evolutionary) public health point of view. As long as the transmission of COVID-19 continues without control in some parts of the globe, no one in the world is safe. However, it is encouraging that there are currently over 169 COVID-19 vaccine candidates under development, with 26 of these in the human trial phase.

III. NAUTILUS INVITES YOUR RESPONSE

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