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Commentary

The Changing Human Relationship with Infectious Disease

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Abstract: The human relationship with disease has undergone significant transformations over time. There is growing scientific consensus that the world is entering a period in which new and reemerging infectious diseases will pose a more significant threat despite the medical and public health advances of the last century. At the current time, U.S. development of countermeasures and prevention and response strategies is not keeping pace. While the changing disease landscape can only be one of many considerations in readiness and operations, an understanding of this context should be one of the factors informing military thought. In this

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commentary, the authors trace the broad transitions in the human relationship with disease, provide an overview of the United States' current status, and highlight some related considerations for the U.S. military.

Keywords: disease, biosecurity, public health, medicine, readiness, globalization, culture

In recent conversations about pandemics and biosecurity at Marine Corps University, people asked, "How did we get here?" The people asking this question were not talking about the last two years of the COVID-19 pandemic or even the last decade. They wanted an explanation of human relationships with disease and to understand how those relationships could affect the U.S. military. The full answer to this question involves the interwoven stories of human and disease evolution, decisions about funding for public health and medical innovation, beliefs about health, and many other issues. It would be far too long for any single article or book. In this commentary, the authors attempt to provide a brief and partial answer, focused on a few key changes in human-disease relationships and military implications.

The history of human interaction with disease has shaped the current context. For the last several decades, humans have been at the beginning of a transition in its relationship with disease that is characterized by the potential for the rapid, global spread of new and reemerging infectious diseases and the fact that, at the current time, medical and public health innovations are not keeping pace. This article is not, for the most part, a commentary recommending specific changes to policies, programs, or resource prioritization. Rather, it is an effort to bring into the conversation a few aspects of the deeper history of human relationships with disease that should be one part of the background informing practical discussions among U.S. military leaders.[1]

Deep History: Early Epidemiological Transitions

One way to simplify the complexity of human relationships with disease during long periods of time is to think about epidemiological transitions.[2] From the early members of the genus *Homo* roughly 2 million years ago, through the emergence of early modern humans around 300,000 years ago, until the growth of settled agriculture around 12,000 to 10,000 years ago, the majority of hominins/humans lived in small, often mobile groups.[3] Although groups did interact, the frequency and intensity of contact was not anything close to what exists today. In these groups, parasites and the occasional zoonotic disease were problems, but infectious diseases that spread from person to person were not as much of a factor as they are today. Even if an infectious disease arose within a group, there were fewer opportunities for it to spread to other groups, fewer opportunities for it to gain a permanent foothold in the species, and fewer chances for more lethal variants to arise.

The first epidemiological transition occurred when some human populations began to practice settled agriculture, around 12,000 to 10,000 years ago. Close and frequent contact with domesticated animals, as well as with nondomestic animals such as rats, created opportunities for pathogens to adapt and become threats to humans. The somewhat larger groups allowed by settled agriculture, along with other factors, allowed infectious disease to become a significant factor in life and death in human populations.

The second transition, from around 300 to 200 years ago until near present day, was associated with the rise of industrialization in some populations and large, often densely settled groups. While initially the larger, more densely settled populations created an increased risk of infectious disease, tremendous advances in medicine and, perhaps more importantly, in public health were the defining characteristic of this transition. Within populations who had access to these advances, the result was a dramatic decline in infectious disease as a cause of death, disability, and social disruption and a greatly increased lifespan.[4] For example, the average life expectancy at birth in the United States increased by 25 years, from 49 to 74, between 1900 and 1980 and was still rising, if more gradually, as the next epidemiological transition was getting underway, reaching 79.4 in 2015.[5] In part due to longer lifespans, as well as changes in nutrition, environmental context, work, and lifestyle, this time period also was characterized by a rise in chronic diseases, such as cancer, heart disease, and diabetes. However, for wealthy populations, this period remained a “golden age” in terms of the preventing or mitigating the impact of infectious disease.

A full discussion of how the United States and other countries funded medical and public health advances and sponsored innovation in these areas is beyond the scope of this commentary, but a few words on the topic are in order. During and immediately following World War II, the United States invested heavily in medical innovation, and much of this work was led by the U.S. Office of Scientific Research and Development (OSRD). OSRD’s mandate was broad, extending well beyond health, but some of the medical innovations that it fostered formed the basis of advances that are taken for granted today, such as the ability to mass-produce antibiotics.[6] The director of OSRD, Vannevar Bush, captured the spirit of the time and the potential for collaboration across government agencies, industry, and academia in the now-famous report, *Science—The Endless Frontier*, which, among other exhortations, called for continued government funding of medical research.[7] Despite Bush's efforts, OSRD was shut down in 1947 and its functions scattered across government agencies.[8]

In the years after World War II, the United States has had ups and downs in terms of how much government attention and funding is given to medical and public health research and infrastructure. There have been a few spikes in attention, most recently those associated with concerns about bioterrorism after the terrorist attacks of 11 September 2001 (9/11), the outbreak of Ebola virus disease (EVD) in West Africa in 2013–16, and the current COVID-19 pandemic. The U.S. Department of Defense (DOD) has continued to be a key player in areas such as vaccine development, collaborating with companies and universities.[9] The tight relationships among government, industry, and academia that fostered so much innovation during and after World War II never truly reemerged, but for a time it seemed that the United States had the pace of innovation it needed to remain competitive with infectious disease.[10]

The Third Transition

The world is now in the third epidemiological transition. Few articles venture to set a start date for this transition, perhaps because it is easier to establish timelines in hindsight. However, it is clear from the related literature that a consensus of concern about novel and reemerging infectious disease began to form in the 1980s and early 1990s.[11] This new transition is characterized by the emergence of novel pathogens and the reemergence of ones previously thought to be eliminated or under control, at least in wealthier nations.[12] It also is characterized by the potential for rapid, wide spread of infectious disease. There are a many factors that contributed (and continue to contribute) to the onset of this transition. However, primary factors generally are thought to be the increased frequency and speed of long-range travel, highly dense populations, the breakdown of public health infrastructure in many places, a changing climate, and social inequality.[13]

The role of social inequality in this transition deserves special mention because it can be difficult to see at first. Not all populations benefitted from the second epidemiological transition before entering third, and there are other populations with significant internal inequality in which segments have experienced the transitions very differently. Put simply, populations or subpopulations with poor living conditions, substandard nutrition, and/or lack of access to health care and public health infrastructure are more vulnerable to disease and more likely to experience un- or poorly mitigated disease spread. This can lead to novel pathogens or new variants of old diseases spreading for long periods of time before governments act or even notice. As Paul E. Farmer put it, "An implication, clearly, is that one place for diseases to hide is among poor people, especially when the poor are socially and medically segregated from those whose deaths might be considered more important."[14] The role that inequality plays in the rise of dangerous pathogens cannot be ignored if this transition is to be navigated successfully.

Certain aspects of the current transition tend to get headlines. The attention of the media and public are captured by the emergence of novel pathogens such as Middle East Respiratory Syndrome (MERS) and SARS-CoV-2 (COVID-19) or the more rapid, broader spread of diseases that previously tended appear in localized outbreaks in poorer countries, such as EVD. However, the reemergence of new forms of pathogens that were previously controlled in many places, such as multidrug-resistant tuberculosis (MDR TB) or necrotizing streptococcus, also are part of the pattern. Antimicrobial resistance (AMR) and the rise of so-called "superbugs" are of concern not only because current treatments are less effective or ineffective against them. Concern also arises from the fact that new treatments are not being developed at anything close to the rate needed to keep pace.[15]

Diseases evolve with human activity and infrastructure as part of their environment, and they can adapt quickly. Humans continue to evolve with every generation, but this process is far slower. As indicated by the very long time periods between the emergence of *Homo sapiens*, then anatomically modern humans and the first epidemiological transition, some of human biology evolved during a time when infectious diseases were not a major driving factor.[16] There have been some disease bottlenecks in particular populations, such as smallpox outbreaks, in which most survivors were those with genetically based immunity or the ability to recover, and those survivors may have passed some of that protection to their children. However, for the most part, humans deal with disease culturally, through health-related beliefs and practices; medical capabilities, technologies, and systems; and public health infrastructure. Typically, cultural adaptation is a good strategy for the species, as it allows humans to adjust to changes in their environment without having to wait generations in hope that biological evolution will provide a beneficial adaptation. Yet, as with all complex cultural patterns, there rarely is complete consensus within a population—let alone across the globe—on what should be done in response to a new disease situation. Consequently, even cultural responses can be outpaced by pathogen adaptations.

Despite the many advantages of the U.S. population, people's cultural patterns, beliefs, actions, and inactions play a role. One example is that public health has suffered from its own success. When public health works, the result is nothing—no cholera outbreaks, no clusters of malaria—and the absence of outbreaks is a hard thing to keep selling to a population that has only recently begun to get a sense that the "golden age" of public health is fading. Public health funding and staffing have leveled off and, in many cases, declined, leaving the U.S. population vulnerable at a particularly risky time.[17]

Infectious disease gained more serious attention in the United States as a national security issue in the mid- to late 1990s and into the mid-2000s. All levels of government and many industries dedicated time and resources to planning for pandemics, outbreaks, bioterrorism, mass vaccination, and other biosecurity events.[18] However, that attention seems to have waned, and many of those who had been involved in planning efforts watched in confusion as the COVID-19 pandemic took hold and many government officials behaved as though such a pandemic was something no one could have predicted and for which there were no plans in place.[19] It remains to be seen if the COVID-19 pandemic will be enough of a wakeup call to spur government agencies at all levels to resurrect their planning and preparedness efforts to address the growing threat of infectious disease.

It also remains to be seen if the current arrangement of governmental, academic, and private capabilities in the United States can be mobilized to meet the challenges of the third epidemiological transition. Early indicators are mixed. As of 2019, the World Health Organization (WHO) reported that there were only 32 antibiotics in clinical development. Of those, only six were categorized as truly innovative.[20] Yet, the United States (and other countries) managed to develop a range of vaccines for COVID-19 in a timeframe that would have seemed impossible not too long ago, when the expectation was that vaccines took a decade or more to be developed and move into production.[21] Some experts see reason for hope, pointing to investments in innovation and acceleration at the National Institutes of Health and elsewhere during the last two decades, if the U.S. populace can muster the collective will to recognize and respond to the context in which it now lives.[22]

The Current State

The previous sections of this article covered, in simplified form, a very long timespan. They touched briefly on aspects of deep and recent history that have played a part in shaping the good and the bad of where the human species is today. In 2022, those living in the United States find themselves in a context of novel and reemerging infectious diseases that can spread around the world at the speed of global travel. Development of vaccines, antimicrobials, and other treatments is struggling to keep pace with the rate of change. Segments of the U.S. population lack easy access to health care and do not have paid sick leave, which make it easier for diseases to spread. As U.S. citizens face challenges that would be difficult, if not impossible, to address without government investment and action, public trust in government is low. In 1958, 75 percent of the U.S. population believed that the government would do the right thing most of the time or always. That rate today is just 20–30 percent.[23] Public trust in health practitioners such as physicians is still high, but trust in medical researchers is significantly lower.[24] In some cases, that lower trust translates into harassment and threats. In a recent *Nature* survey of researchers who had spoken out about COVID-19, nearly 60 percent reported that they had experienced attacks on their credibility, more than 20 percent received threats of physical or sexual violence, and 15 percent received death threats. The same study found that researchers who were subjected to "trolling" or other attacks said that the experience affected their willingness to speak publicly in the future, a situation that the country can ill afford at a time when the public needs more, not less, information about disease risks.[25]

Meanwhile, public understanding of basic scientific processes and facts is not what one would like to see as the United States moves into what will be, of necessity, a science-heavy effort to meet the challenges of the third epidemiological transition. This is not to suggest that the U.S. public is inherently ignorant. However, people who do not use basic scientific knowledge in daily life forget what they learned in high school or introductory science classes in college. They also are focused on other things in life. Yet, the collective impact creates a situation in which the public is not well prepared to participate in a national discussion about the complex, scientific questions and issues that the country faces. For example, in 2014 the National Science Board (NSB) found that only 55 percent of respondents were able to correctly identify that it takes the Earth a year to go around the sun, and only 51 percent were able to answer correctly a question about whether antibiotics can be used to treat viral infections. Most could answer correctly only about half the questions on rudimentary scientific knowledge.[26] Some of the implications of this knowledge gap played out in public confusion about risks to the U.S. population and public health guidelines during the West Africa EVD outbreak in 2013–16.[27] The COVID-19 pandemic also has made it clear that, even setting aside deliberate misinformation and the segment of the population that simply does not accept science, building public understanding is challenging in situations such as outbreaks of novel diseases or new variants during which the science is being done as events unfold.[28] On a more positive note, a more recent NSB examination of public knowledge did produce some more heartening findings. For example, 66 percent of respondents understood that the scientific method produces findings that may be tested and change over time and 50 percent demonstrated evidence of knowing what a hypothesis is.[29]

In addition to the somewhat worrisome statistics above, the United States also is facing a lag in people's ability to perceive the changes in their context. Many citizens, including elected officials and government agency leaders, were born, raised, and formed their beliefs about health and disease in the years when the benefits of the second epidemiological transition were at their height. They came of age during a time when public health was well supported and effective (or at least not in steep decline), when much of the population was vaccinated against known diseases, when antibiotics still worked against most common infections, and when promising new antivirals and other drugs were being developed to address some of the more intractable disease challenges, such as human immunodeficiency virus (HIV). Many people still talk as though the country is just one innovation away from going back to that time, or as though they had never left it. There is not yet enough discussion of what new kind of "normal" should be built for the future.

Yet, this is not a tale of doom. The human species is highly adaptable, using cultural changes to meet challenges both large and small. Humans have survived previous epidemiological transitions and can adapt to this one, but doing so in a time of global connectivity will take thought, effort, and resources. It will not happen automatically. Perhaps most importantly, because infectious disease is simultaneously an individual, national, and global problem, confronting the challenges of the third transition cannot happen solely in academia, the biomedical industry, or the government, although advances in public health and medicine as well as policy shifts are necessary.[30] It also must involve changes in individual orientations toward what people do when they are sick and awareness of how their choices affect their communities.

The Third Transition and the Military

How does any of this affect the U.S. military? The authors' primary purpose in writing this commentary is to highlight an aspect of the current environment in the United States that should inform military thinking rather than try to make claims about what that thinking should be. Moreover, given all the other transformational challenges facing the military, the third epidemiological transition can only be one consideration out of many. Still, there are a few dots that can be connected.

The military inherits the disease environment created by the decisions of elected officials and the public, both in the United States and abroad. If the current state continues, the environment may be marked by an increasing number of outbreaks and pandemics with relatively low investment in the biomedical innovations and public health infrastructure needed to counter them and continued division in the U.S. population about how to prevent or address disease crises. This could create significant challenges for military readiness and operations. In contrast, if investment increases and the population is able to reach effective compromises in what prevention and response measures it will accept, there will be fewer disease threats that pose serious or significant risks to the military. The reality for which the military has to prepare is likely to be somewhere in between these two possible futures.

The DOD already considers medical readiness to be part of operational readiness.[31] Navigating changes to improve operational readiness in the face of potentially increased disease threats will necessitate consideration of several internal and external factors that directly impact medical readiness. These factors include current healthcare policies, organizational culture, and leadership styles that advocate (or do not advocate) for military support services such as organizational child care. Still, the initial concern for readiness is the basic health of the force. If a pathogen emerged causing illness and death among large numbers of young, relatively healthy individuals, as was the case with the 1918 influenza pandemic, readiness could be degraded.[32] It is not necessary that the pathogen have a high mortality rate to affect readiness. Illness serious enough to render a large number of individuals ineffective is enough to cause disruption.[33] When it comes to infectious diseases for which vaccinations or treatments do not exist or are not available, especially diseases that are easily transmissible through respiration, the key to stopping them is awareness and behavioral adaptation.

While not perfect, the U.S. military performs relatively well in this area of readiness. From the first moments of their indoctrination, servicemembers experience tight operating and living conditions—from open squad bays in boot camp to crowded berthing in the enclosed spaces of a submarine—which are all excellent transmission environments for infectious disease. Weekly "field day" cleaning evolutions were born out of this concern. Although some young servicemembers may believe this is a punishment (e.g., "Liberty is secured until field day is complete"), the intent is to keep spaces as hygienic and safe as possible. Behaviorally, servicemembers follow orders. This may sound simplistic, but when it comes to changing observable behaviors because of policy change, there is not as much room for noncompliance in the military as there is in the civilian population. Additionally, DOD policy requires each military department be responsible for ensuring that its individual servicemembers are medically ready.[34] Such readiness standards include annual physical health assessments, dental readiness ratings, up-to-date immunizations, and relevant laboratory studies.

These measures supported sufficient readiness in the past, but it is worth considering whether or not the same measures will be adequate for the future. When preparing for emerging, potentially swift, and highly transmissible diseases, the question will be: "Are we ready enough to deploy?" Obviously, perfect readiness for all potential medical and public health challenges is not achievable and tilts too far in the direction of safety, doing more harm than good. It will be necessary to find a new balance.

If and when future outbreaks and pandemics rise to the level of becoming national and global threats, the science of understanding how to identify and defeat or mitigate diseases will also continue to evolve. In the case of the global influenza pandemic that began in 1918, military installations and travel were key elements of how the disease spread.[35] A century later in 2020, just two days after the WHO declared that COVID-19 had reached pandemic levels, the DOD issued a stop move order prohibiting temporary travel orders, permanent change of station moves, and personal travel. Deployments were curtailed and rotations extended.[36] The DOD also was a significant force in the development of vaccines and treatments for COVID-19 through partnerships with the private sector and the U.S. Department of Health and Human Services.[37] The relative costs and benefits for military and civilian populations of some of the preventative measures likely will be debated for years, but the responses and engagement indicate an evolution of military thought about the connection between public health and readiness. The risk calculus for the military will always be complex and dynamic to meet specific challenges in specific contexts. Ongoing policy reviews and exercises or wargames, as well as better linkages to public health experts to inform decision making, will continue to be important.

However, even if military departments continue to refine decision-making processes and responses, behavioral change may lag. This lag can be mitigated by improving military personnel's awareness of public health, which can be accomplished without attempting to turn servicemembers into lay-scientists. Military leaders can gradually normalize disease mitigation measures and show that adherence to them is valued. This will require both active attention from leaders and effort to model the desired behaviors. Some of the measures necessary to mitigate the spread of infectious disease (e.g., staying home when exposed or sick, social distancing, wearing a mask, etc.) are at odds with the culture of many military organizations in which working through injury or illness is seen as dedication to the mission rather than something that puts readiness at risk.

Other readiness issues include refining plans for managing family exposure to a disease of concern as well as actual illness. Based on the authors' conversations with Marine parents during the COVID-19 pandemic, the effect of infectious disease exposures and outbreaks on childcare demands special attention, as the unpredictable closing of schools and daycare centers due to exposures and cases has made it very difficult to get into an acceptable routine. The mental health impacts on military personnel of both disease (whether the servicemember or family) and mitigation measures such as quarantine also require further study.[38] Preparing for the environment outside the DOD's control is another way to mitigate risks to medical and, consequently, operational readiness. Considerations of U.S. public opinion matter, as do the economy, technology, and political and social conditions.

If the knowledge trends described earlier regarding trust and scientific knowledge hold true for the U.S. military population, one of the key actions for readiness will be to gradually raise the level of awareness of infectious disease as an important issue. In future outbreaks or pandemics, the military can require mitigation measures such as masks, vaccinations, and social distancing. However, forcing such measures when a large portion of the population is unaware of or does not accept the risks as serious is likely to be disruptive and divisive and may not be effective. This is especially true if the military is proactive about such measures, which inevitably will mean that mitigation measures are enacted in some situations in which the threat does not turn out to be as significant as initially thought. False alarms can desensitize people, causing them to ignore instructions, a pattern seen with weather alerts such as tornado warnings.[39] Again, the challenge for military leaders will be to find a new balance that enhances the ability to maintain readiness in a new disease context without creating a level of constraint to which military personnel are unwilling to adapt.

Detailed examination of operational considerations is outside the scope of this commentary, but there are few broad areas in which the third transition should be one of the many factors informing the thinking of military leaders. Of course, adversary attacks with pathogens will always be a concern, but here the focus is on risks that are not deliberately created. Disease risks are already included in some assessments of areas of operations and overseas bases, but the increasing potential for novel and reemerging infectious disease might be cause for a finer grained level of surveillance. Noticing that there seems to be a bad cold circulating within a population takes on a different level of significance when one is not sure it is really just a cold.

It also is reasonable to assume that the current disease environment will mean that the military may be called on more frequently to support operations in disease-related crises both domestically and abroad. While each operation would have different characteristics, response to infectious disease crises requires enhanced force protection measures, potentially impacting what units can and cannot effectively accomplish. Disease-related support operations also have a significant tail in terms of ensuring that military personnel do not return to the United States, the fleet, or overseas bases with unintended cargo in the form of a transmissible infection. In Operation United Assistance (OUA), the response to the 2013–16 outbreak of EVD in West Africa, the initial policy was that returning personnel assessed to have an elevated risk of exposure were required to quarantine at a DOD facility for 21 days. Other returning personnel were monitored for 21 days but otherwise could go about their normal lives. This policy shifted in just a few weeks to "controlled monitoring," during which returning personnel without elevated risk were required to be sequestered in cohorts for 21 days prior to returning to normal life. These policies, the rapid changes, and the lack of uniformity across all government agencies, were confusing and difficult for returning personnel and their families.[40] There likely are lessons learned from operations such as OUA and the DOD's experience with COVID-19 that can be mined to plan for future disease crises, work that hopefully is already underway.

As with readiness, when considering operations, it is neither desirable nor feasible to try to turn military planners and commanders into epidemiologists. It is more realistic to build their capacity to identify and use necessary experts when they are needed. Even something as simple as deepening the number of decision makers who understand the differences between the skills that medical and public health professionals bring to the table and how to support their logistics needs (e.g., refrigeration, transportation, airlift, access, and shipping) would be a positive step.[41] Beyond that, helping more leaders build their understanding of the different contributions that behavioral and social scientists can make to readiness, force protection, and operational planning would expand the military's toolkit for preventing, mitigating, or operating in the middle of an infectious disease outbreak or pandemic.

Today, the U.S. military and the U.S. Agency for International Development (USAID) work together frequently to support global initiatives that involve global health crises of various types and grades. Enablers such as the USAID Office of Civilian-Military Cooperation exist because aligning development and defense goals and leveraging the capabilities of both parties is extremely complex. DOD exposure to USAID is already established, but the conduct of timely and frequent comprehensive reviews of personnel exchanges, policy development, and directed training and exercises with USAID and other agencies such as the Centers for Disease Control and Prevention are critical to maintaining awareness and relationships.

Conclusion

If those who developed the epidemiological transition model and others concerned about the rising threat of infectious disease are correct, the human species is now living in a very different and more dangerous disease environment. Over time, that environment may reshape the daily lives of individuals as well as the national security environment in both overt and subtle ways. It is important that this reality be one of the factors informing the thinking of those making consequential decisions, including those responsible for the lives of U.S. military personnel and the force's effectiveness in operations. The United States and the larger international community may not be able to get back to a "new normal" that looks like the past. However, if due attention is paid, humans can chart their own course, choosing their adaptations rather than having them forced upon the species by disease outbreaks, and, in the process of adapting, perhaps reshape the path of third epidemiological transition.

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[1] To facilitate reader access to additional information and source material, wherever possible, the authors have provided references that are written in an accessible style and are publicly available without the need for subscriptions to scholarly databases.

[2] Except where otherwise cited, the transition model described in this commentary is based on the work of biological anthropologist George J. Armelagos, which was developed and refined in collaboration with medical anthropologists, epidemiologists, and others. This model was based on work by epidemiologist Abdel R. Omran in the 1970s. Transition models are simplifications meant to capture broad changes during very long stretches of time. They do not capture all the complexities involved in human-disease interactions and tend to be tilted toward the experiences of wealthy populations. The experiences of poorer or colonized populations often did not follow a pattern of gradual transition. Instead, epidemiological changes were often fast and harsh, with little time for the populations to develop cultural adaptations to mitigate impacts. For an accessible overview of some of the impacts of colonization on health in the Americas, see Heather Pringle, "How Europeans Brought Sickness to the New World," *Science*, 4 June 2015; George J. Armelagos, Kathleen C. Barnes, and James Lin, "Disease in Human Evolution: The Re-Emergence of Infectious Disease in the Third Epidemiological Transition," *Anthro Notes* 18, no. 3 (1996): 1–7, https://doi.org/10.5479/10088/22354; Kristin Harper and George J. Armelagos, "The Changing Disease-Scape in the Third Epidemiological Transition," *International Journal of Environmental Research and Public Health* 7, no. 2 (2010): 675–97, https://doi.org/10.3390/ijerph7020675; Abdel R. Omran, "The Epidemiologic Transition Theory Revisited Thirty Years Later," *World Health Statistics Quarterly* 51 (1998): 99–119; Abdel R. Omran, "The Epidemiologic Transition: A Theory of the Epidemiology of Population Change," *Milbank Quarterly* 49, no. 4 (1971): 509–38; Abdel R. Omran, "A Century of Epidemiologic Transition in the United States," *Preventative Medicine* 6 (1977): 30–51; and Ron Barrett and George J. Armelagos, "An Unnatural History of Emerging Infections," *General Anthropology* 21, no. 2 (2014): 1–4, https://doi.org/10.1111/gena.01000.

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[9] Hoyt, *Long Shot*; and Silvia Ratto-Kim et al., "The U.S. Military Commitment to Vaccine Development: A Century of Successes and Challenges," *Frontiers in Immunology* 9 (2018): 1397, https://doi.org/10.3389/fimmu.2018.01397.

[10] The reasons for this are fascinating but beyond the scope of this commentary. Readers interested in learning more may wish to consult the following references: Dietmar Braun, "Lasting Tensions in Research Policy-Making: A Delegation Problem," *Science and Public Policy* 30, no. 5 (October 2003): 309–21, https://doi.org/10.3152/147154303781780353; Daniel J. Kevles, "Principles and Politics in Federal R&D Policy, 1945–1990: An Appreciation of the Bush Report," in *Science—The Endless Frontier: A Report to the President on a Program for Postwar Scientific Research*, National Science Foundation 40th Anniversary ed. (Washington, DC: National Science Foundation, 1990), ix–xxxiii; Daniel J. Kevles, "What's New about the Politics of Science?," *Social Research* 73, no. 3 (Fall 2006): 761–78, https://doi.org/10.1353/sor.2006.0052; Hoyt, *Long Shot*; and Kerry Fosher, "Reflections on Current Research: Science and Scientists in Military Organizations," *Journal of Culture, Language, and International Security* 1, no. 2 (Winter 2015): 47–58.

[11] David Satcher, "Emerging Infections: Getting Ahead of the Curve," *Emerging Infectious Diseases* 1, no. 1 (January–March 1995): 1–6, https://doi.org/10.3201/eid0101.950101; David P. Fidler, "Globalization, International Law, and Emerging Infectious Diseases," *Emerging Infectious Diseases* 2, no. 2 (April–June 1996): 77–84, https://doi.org/10.3201/eid0202.960201; Paul E. Farmer, "Social Inequalities and Emerging Infectious Diseases," *Emerging Infectious Diseases* 2, no. 4 (October–December 1996): 259–69, https://doi.org/10.3201/eid0204.960402; Mary E. Wilson, "Travel and the Emergence of Infectious Diseases," *Emerging Infectious Diseases* 1, no. 2 (April–June 1995): 39–46, https://doi.org/10.3201/eid0102.950201; and Joshua Lederberg, Robert E. Shope, and Stanley C. Oaks Jr., eds., *Emerging Infections: Microbial Threats to Health in the United States* (Washington DC: National Academies Press, 1992).

[12] See discussion of the biases and limitation of the transition model in footnote 2.

[13] Wilson, "Travel and the Emergence of Infectious Diseases"; Harper and Armelagos, "The Changing Disease-Scape in the Third Epidemiological Transition"; and Colin J. Carlson et al., "Climate Change Increases Cross-Species Viral Transmission Risk," *Nature*, 28 April 2022, https://doi.org/10.1038/s41586-022-04788-w.

[14] Farmer, "Social Inequalities and Emerging Infectious Diseases."

[15] For an accessible overview of drug resistance and the drug development pipeline problem, see "Fact Sheet: Antimicrobial Resistance," World Health Organization, 17 November 2021.

[16] Although all *Homo sapiens* are considered to be the same species, there have been some phenotype patterns that have shifted in the species over time. The term *anatomically modern humans* is used to describe populations of *Homo sapiens* that are within the same range of phenotypes seen in the species today.

[17] It can be challenging to say exactly how much U.S. public infrastructure has declined in the last half century. Figures vary depending on whether the metric used is organizational budgets, percentage of overall health spending, or the sufficiency of the public health workforce and whether one looks at the national, state, or local levels. Moreover, a few temporary fiscal upticks associated with post-9/11 interest in biosecurity and the current COVID-19 pandemic muddy statistical analysis. However, there is general consensus that the U.S. capacity for public health has steadily declined with effects that are particularly concerning at the state and local level, which is a key interface with the public. William Eger and Margaret House, "Confronting a Legacy of Scarcity: A Plan for Reinvesting in U.S. Public Health," *Stat*, 28 June 2021; Rhea K. Farberman et al., *The Impact of Chronic Underfunding on America's Public Health System: Trends, Risks, and Recommendations, 2020* (Washington, DC: Trust for America's Health, 2020); Lauren Weber, Laura Ungar, and Michelle R. Smith, "Underfunded and Under Threat: Hollowed-out Public Health System Faces More Cuts amid Virus," *Kaiser Health News*, 1 July 2020; and *National Profile of Local Health Departments* (Washington, DC: National Association of County and City Health Officials, 2019).

[18] William J. Clinton, "Emerging Infectious Diseases," Presidential Decision Directive NSTC-7 (Washington, DC: White House, 1996); *The Global Infectious Disease Threat and Its Implications for the United States* (Washington, DC: National Intelligence Council, 2000); *National Strategy for Pandemic Influenza* (Washington, DC: Homeland Security Council, November 2005); Gary Cecchine and Melinda Moore, *Infectious Disease and National Security: Strategic Information Needs* (Santa Monica, CA: Rand, 2006); and Yong-Bee Lim, David Gillum, and Kathleen Vogel, "Twenty Years after the Patriot Act, What Is the Future of Biosecurity?," *Issues in Science and Technology*, 25 October 2021.

[19] Prior to working with the DOD, Fosher was at Dartmouth (now Geisel) Medical School, where she worked on pandemic planning and related matters at the local, state, and regional levels.

[20] "Fact Sheet: Antimicrobial Resistance."

[21] "Timeline: The History of Vaccines," College of Physicians of Philadelphia, accessed 1 December 2021.

[22] Kendall Hoyt, "Vaccines Weren't Ready for Ebola. We Can Do Better," *Wired*, 27 August 2015.

[23] "Public Trust in Government: 1958–2021," Pew Research Center, 17 May 2021.

[24] "Trust and Mistrust in Americans' Views of Scientific Experts," Pew Research Center, 2 August 2019.

[25] Bianca Nogrady, "Scientists under Attack," *Nature* 598 (14 October 2021): 250–53, https://doi.org/10.1038/d41586-021-02741-x.

[26] "Science and Engineering Indicators, 2014," National Science Foundation, February 2014; and Fosher, "Reflections on Current Research."

[27] Kerry B. Fosher, "Patterns in Our Problems: U.S. Response to Health Crises," *Journal of Culture, Language, and International Security* 1, no. 2 (Winter 2015): 72–76.

[28] David W. Oxtoby and Richard A. Meserve, "Implications of COVID-19 and the Public Face of Science," American Academy of Arts and Sciences, 2020.

[29] *Science and Technology: Public Perceptions, Awareness, and Information Sources*, Science and Engineering Indicators (Alexandria, VA: National Science Foundation, 2022). As the questions asked in the Science and Engineering Indicators studies changed between 2014 and 2022, it is therefore not possible to conduct a direct comparison across the years.

[30] The future of biomedical research and development, health policy, and public-private partnerships is beyond the range of this commentary. Accessible discussions of many of the key issues can be found in the work of Kendall Hoyt, who works in the areas of health security, innovation policy, and vaccine development. See, for example, Hoyt, *Long Shot*; Hoyt, "Vaccines Weren't Ready for Ebola"; and Kendall Hoyt and Tom Johnston, "A Plan to Break the Vaccine Manufacturing Bottleneck," *Barron's*, 25 May 2021.

[31] "Individual Medical Readiness (IMR)," Department of Defense Instruction no. 6025.19 (Washington, DC: Department of Defense, 2020).

[32] The reasons for the susceptibility of young people during the 1918 influenza pandemic are still being studied. Although the virus caused serious, debilitating illness in many, most deaths were not caused by the influenza itself but rather by secondary pneumonia. One current explanation is that earlier exposure to a different influenza virus may have led to an immune response to the 1918 virus that left people more susceptible to bacterial respiratory illness. G. Dennis Shanks and John F. Brundage, "Pathogenic Responses among Young Adults during the 1918 Influenza Pandemic," *Emerging Infectious Diseases* 18, no. 2 (February 2012): 201–7, http://dx.doi.org/10.3201/eid1802.102042; and Ruth Craig, "Why Did the 1918 Flu Kill So Many Otherwise Healthy Young Adults?," *Smithsonian Magazine*, 10 November 2017.

[33] Carol R. Byerly, "The U.S. Military and the Influenza Pandemic of 1918–1919," *Public Health Reports* 125, no. 3 (Supplement) (April 2010): 82–91.

[34] "Individual Medical Readiness (IMR)."

[35] Jeffery K. Taubenberger and David M. Morens, "1918 Influenza: The Mother of All Pandemics," *Emerging Infectious Diseases* 12, no. 1 (January 2006): 15–22, https://doi.org/10.3201/eid1201.050979.

[36] Domenico Cucinotta and Maurizio Vanelli, "WHO Declares COVID-19 a Pandemic," *Acta Biomedica* 91, no. 1 (2020): 157–60, https://doi.org/10.23750/abm.v91i1.9397; and "Stop Movement for All Domestic Travel for DoD Components in Response to Coronavirus Disease 2019," Department of Defense Memorandum (Washington, DC: Department of Defense, 2020).

[37] John E. Hall and LtCol Nate Packard, "Operation Warp Speed and the Countermeasures Acceleration Group—A Twenty-First Century Manhattan Project: Preliminary Observations on the U.S. Department of Defense's Role in the Supply, Production, and Distribution of COVID-19 Vaccines and Therapeutics," *Journal of Advanced Military Studies* 31, no. 1 (Spring 2022): 144–62, https://doi.org/10.21140/mcuj.20221301007.

[38] A concise overview of the state of military mental health research related to outbreaks and pandemics can be found in Timothy Berger, "The Psychological Impacts of the COVID-19 Pandemic on the U.S. Military," *Journal of Advanced Military Studies* 13, no. 1 (Spring 2022): 163–78, https://doi.org/10.21140/mcuj.20221301008.

[39] Rick Atterberry, "Why Do People Ignore Tornado Warnings?," *EDE Notes* (blog), 7 May 2012.

[40] *Operation United Assistance: The DOD Response to Ebola in West Africa* (Suffolk, VA: Joint and Coalition Operational Analysis, 2016).

[41] There is overlap in the educational backgrounds of medical and public health professionals, but they typically have distinct perspectives and skills. Medical professionals generally focus on individuals, whereas public health professionals focus on populations. So, as one probably would not go to an epidemiologist for an annual physical, a medical doctor usually is not the ideal person to consult on how to mitigate the spread of disease in a population. Both types of expertise are important in addressing infectious disease, but they address different parts of the problem. As is always the case in the DOD, sometimes commanders have to make do with the expertise they can access, but it is good to understand the different sets of knowledge and skills available when there is a choice to be had.