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FROM THE EDITOR

Emerging Infectious Diseases at the Intersections of Human, Animal, and Environmental Health

Ariadne A. Nichol

The health of humans, animals, and their shared environments is inextricably interconnected. These connections are particularly evident in the increase in infectious disease emergence in recent decades.[1,2] Up to 75% of emerging infectious diseases are zoonotic, ie, caused by viruses and other microbes "spilling over" from nonhuman to human animals.[1,3] Such infections can be deadly, as seen with Ebola, SARS, MERS, and, more recently, COVID-19. Fatality rates in some Ebola outbreaks have been as high as 90%.[4] Climate change elevates risk of cross-species transmission events and epidemics,[5,6] along with disruption of natural ecosystems (eg, deforestation, extractive industry, farming practices) that increase interaction among human and nonhuman animal reservoirs and create more opportunities for microbes to jump species. A 2022 World Bank report states: "Sixty percent of the drivers of the 100 biggest outbreaks since 1974 fall within the domains of land-use change, especially related to forests and food systems, in particular livestock operations."[7]

Risk of zoonotic spillover increases in areas where human and nonhuman animals come into close proximity, such as areas where live markets or some hunting practices are common. Greater, more rapid movement of people and nonhuman animals also means emerging diseases can quickly spread regionally and globally, highlighting the urgent need to apply interdisciplinary approaches to prevent pathogen spillover and transmission.[7,8] One such approach is One Health, defined by the World Health Organization as "an integrated, unifying approach that aims to sustainably balance and optimize the health of people, animals and ecosystems. It recognizes that the health of humans, domestic and wild animals, plants, and the wider environment (including ecosystems) are closely linked and interdependent."[8]

Although this approach emphasizes cross-disciplinary collaboration among epidemiologists, public health authorities, community leaders, ecologists, vaccine developers, and veterinarians to address disease control and transmission prevention, conflicts about priorities can emerge that raise ethical questions. Low- and middle-income countries are frequently at higher risk of spillover events,[9] and they can be inequitably harmed during epidemics.[10] Work at the intersection of clinical, agricultural, and wildlife communities is often complex and fraught with competing interests and differing cultural values. For example, a Nipah virus outbreak in Malaysia from September 1998 to May 1999 was thought to result from local ecological changes that brought the virus host bats in close proximity to intensive pig farming operations, with subsequent viral spillover from bats to pigs to humans.[11] The epidemic was eventually controlled by medical-agricultural collaboration and involved the slaughter of over a million pigs, which had important fiscal consequences for farmers.[12] This example highlights the need to balance livestock and public welfare when promoting sustainability.

Another such example is SARS-CoV-2, which may have originated from spillover from bats to humans via a live animal wet market.[13,14] Interestingly, since 20% of mammal species are bats,[15] bats are frequently implicated as potential sources of emerging human diseases.[16] Yet bats are also essential parts of healthy ecosystems, and efforts to reduce spillover infections to humans by simply culling bat populations have often resulted in increased virus transmission risk.[17,18] Interdisciplinary approaches are thus key to responding to emerging infectious diseases, zoonotic spillover, changing ecological landscapes, and disease transmission trends.

A third example of spillover events that highlights the need for interdisciplinary collaboration is Rift Valley fever. Occurring in both livestock and humans—with farmers, herders, veterinarians, and slaughterhouse workers at highest risk—Rift Valley fever periodically causes devastating epidemics in certain regions of Africa and the Arabian Peninsula.[19,20] Key effective public and environmental health collaboration efforts can include vaccinating nonhuman animals, which protects them and reduces human infection risk. Yet doing so requires financial and political players' participation.[21] Such examples and their social, cultural, and ethical complexities are considered in detail in this issue of the *AMA Journal of Ethics.*

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CASE AND COMMENTARY

Which Factors Matter Most When Using Vaccines to Combat Zoonoses?

Erica Kaufman West, MD

Abstract
Zoonoses are infectious diseases that pass from an animal to a human. Of all emerging pathogens studied, zoonoses are the majority. As was seen with SARS-CoV-2, zoonoses can cause enormous morbidity and mortality around the world. Curbing these infections is of great interest, but combatting infections that start in various animal species comes with a multitude of challenges.

Case

Dr Z is a zoonotic infectious diseases specialist giving a talk as part of a panel session at a conference about emerging epidemic and pandemic disease transmission from nonhuman to human animals. Dr Z explains that some microbes do not cause disease in livestock or wild nonhuman animals but that nonhuman animal pathogens can "spill over" to humans. Dr Z offers examples: Nipah virus from fruit bats spreads to livestock and humans, Middle East Respiratory Syndrome (MERS) CoV spreads from camels to humans, and Crimean-Congo hemorrhagic fever virus is carried by ticks to livestock and humans. Dr Z then describes how vaccinating both domestic and wild nonhuman animals can mitigate much of the transmission to humans.

Commentary

Of all emerging pathogens studied, about 75% are due to zoonosis.[1] The United States Agency for International Development (USAID) project PREDICT, run by the UC Davis One Health Institute, has discovered over 900 novel viruses in its surveillance around the world.[2] While not all of these viruses can jump from nonhuman to human animals, some certainly do. Controlling zoonotic threats from livestock and companion animals is not new. Dr Z can elaborate on several ways to protect the human population. Controlling vectors of disease transmission can be as straightforward as eliminating standing water where mosquitos breed or as complex as genetically modifying flying insects. Animal inoculation, another method of control, is an ancient practice that opened the door to the science of vaccination in both animals and humans. However, a more novel approach is to vaccinate individuals of the species that transmit the disease.

Insecticides and Genetic Modification

Dr A could point out that we already mitigate the risk of zoonoses through nonvaccine prevention methods. Mosquito control programs, such as using insecticides, are old and often effective temporarily. With time, however, resistance to insecticides can occur,[3] and these programs require vigilance to keep the population in check. Genetic modification of mosquitos—specifically, *Aedes aegypti* mosquitoes that transmit Dengue and Zika viruses, among others—is also effective,[4] although not without controversy.[5] These genetically modified mosquitoes are released into the wild, where they can lay eggs carrying the same modified genes, leading to death of the mosquito before adulthood. With time, the population of this specific mosquito species (but not others) will decline but not be eliminated. If the genetically modified mosquitos are not continually released year after year, the population will return to "normal levels." Effective mosquito control programs thus incorporate multiple modalities, such as a combination of irradiation, larvicides, and monitoring standing water, to have the largest impact.[6]

Animal Vaccination

Dr A could note that though vaccinating humans helps reduce morbidity and mortality in people, it does nothing to eliminate the threat of disease. To do that, we must inoculate the animal population that the pathogen first infects. If we can rid the primary host of the infection, then we will prevent future disease in that species and in secondary species, such as ours.

Dr Z could explain that protecting livestock via vaccination protects humans in a variety of ways. We vaccinate household pets for many diseases, such as rabies and leptospirosis, which can infect both animals and humans.[7] Vaccinating livestock helps prevent foodborne diseases, such as cysticercosis (from *Taenia solium*) and toxoplasmosis (from *Toxoplasma gondii*), which can devastate livestock populations as well as cause human infections. According to Sander et al, "It is generally accepted that the administration of vaccines for foodborne infections is the best-available public health intervention" not only for improving the overall health and reducing the mortality of both animals and humans, but also for promoting socioeconomic development in communities that rely on livestock for their livelihood.[8]

Nevertheless, animal vaccines are not without some risks. For example, there have been reports of accidental human inoculation with *Brucella* vaccines developed for cows and sheep.[9] The Centers for Disease Control and Prevention tracks these cases and has information for post-exposure prophylaxis for veterinarians or others accidentally exposed.[10]

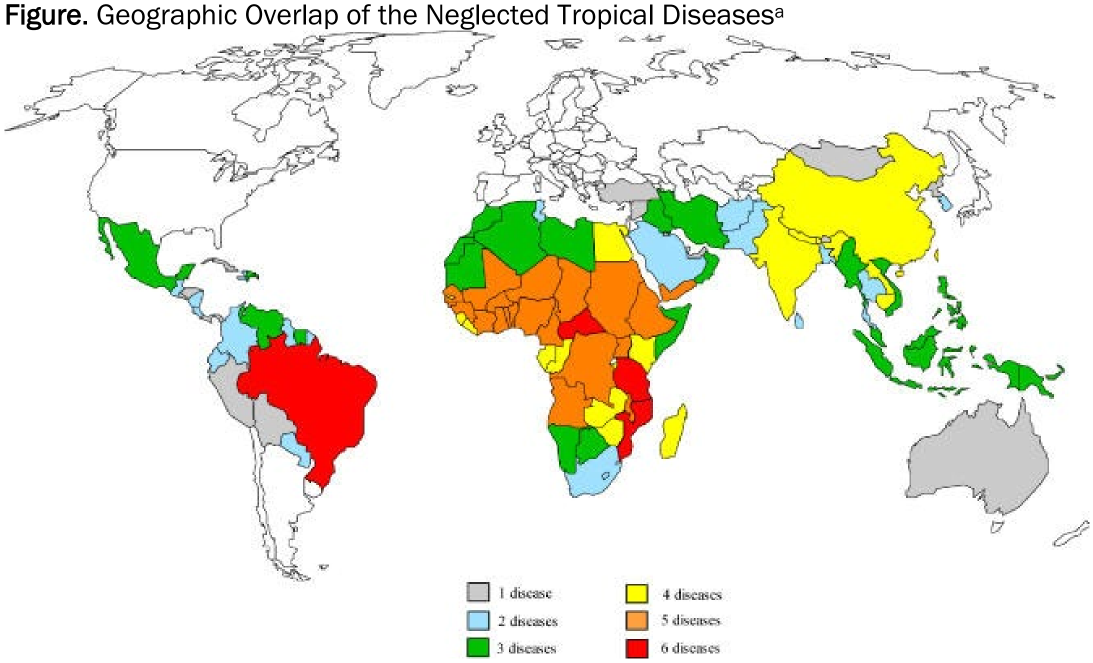
Moreover, these traditional vaccines are of limited value. While we often think of vaccines in an injectable form for one person, scientists have developed different vaccine types that promote self-dissemination in animals. For example, putting a vaccine on a bat's fur is an example of a *transferable* vaccine. That bat may encounter a dozen other bats, thereby transferring the vaccine through typical colony grooming behaviors. However, the vaccination effort stops there. The newly vaccinated bats do not have any vaccine on their fur, so they will not transfer any vaccine to others. *Transmissible* vaccines require an initial injection, but then that animal can transmit the vaccine to others via typical social interactions.[11,12] The transmissibility of the vaccine will determine how long it persists within the species. If the basic reproductive number, the R_0, of the vaccine, is low, then the vaccinated animal might not actually pass it along to another animal of the same species. The theoretical benefit of transmissible vaccines is that vaccines with a high R_0 will have an extensive horizontal spread.[13] Those secondarily vaccinated animals can then transmit the vaccine when they interact with other animals. While transmissible vaccines might cause a faster rise in the number of vaccinated animals, unintended consequences, if any, will persist in the population as well. Dr A must report that both types of self-disseminating vaccines require expert knowledge of the pathogen target, the reservoir host immune system and behaviors, and possible consequences of the vaccination efforts.[14]

Protecting the Most Vulnerable

Most zoonoses are considered tropical diseases, and many fall into the category of neglected tropical diseases (NTD),[15] which are often due to poor sanitation and crowded living conditions, exacerbated by personal poverty and a lack of protective systems in the country. NTDs are ancient diseases that have been afflicting the poorest on this planet for centuries. Another hallmark of NTDs is that they cause chronic, debilitating symptoms and have a relatively low mortality rate.[16] As a result, people live with disfigurement, become unable to work, and are further subjected to poverty and stigmatization. In many areas, children are infected with parasites like hookworm and become anemic and malnourished,[16] making it difficult to learn (if schooling is an option) and difficult to work and earn a wage.[15]

NTDs mainly affect people in Asia, Africa, and Latin America (see Figure). As such, preventing transmission of NTDs is also a matter of equity and social justice that cannot be ignored. These areas and diseases are all but forgotten in the high-income countries where vaccine development occurs. Because there is no traditional commercial market for vaccines for infections like NTDs, vaccine development has been slow or nonexistent. There have also been technical difficulties in finding human vaccines for these diseases.[16]

Figure. Geographic Overlap of the Neglected Tropical Diseases[a]



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[a] Map prepared by Molly Brady, Emory University.

High-income countries, Dr A can point out, must realize that the risk of a tropical disease in their lands is not as far off as they might think. There have been recent cases of “homegrown” malaria in the United States,[18] after mosquitoes native to the United

States bit people who returned with malaria after a trip abroad. These mosquitoes could then bite and infect the traveler's contacts, perpetuating the infection cycle when the contacts in turn get bitten by mosquitoes. Similarly, there was a case of Dengue virus infection in the United States of a person who lived near someone who had returned with the virus after traveling to an endemic region.[19]

As we have seen during the COVID-19 pandemic, improving public health structures in developing countries benefits everyone. While the rapid development of the SARS-CoV-2 vaccine, which relied heavily on previous vaccines for other coronaviruses, has raised hopes for development of vaccines for NTDs, companies are not incentivized to develop vaccines for persons who cannot pay for them. Restructuring this financial model is essential but will take time. Other options must be explored.

Where to invest our research efforts remains unclear. Working on human vaccines would have some advantages, as most NTDs have a clear geography. However, many populations suffer from the risk of more than one NTD (see Figure), so human vaccines would need to offer protection for multiple diseases (eg, Tdap vaccines offer protection against tetanus, diphtheria, and pertussis with one shot) to maximize the reach of a vaccine campaign. The implementation of any mass vaccination campaign would require Herculean investment of financial, human, and educational capital. While challenges of developing animal vaccines are clearly different, they also would require significant investment. Wealthier countries must recognize that it is in their self-interest to tackle these diseases now rather than risk outbreaks in the future.

Summary
Zoonoses remain a major global threat. Reacting to a pandemic, as we saw with COVID-19, is costly both in financial terms as well as in human lives lost. It is essential to be proactive, lest we lose another almost 7 million people in the next pandemic.[20] Carpenter et al note: "The potential for zoonotic diseases to affect human, animal, plant, and environmental health, global food security, and economic stability highlights the need for effective interventions that target prevention at multiple levels."[21] Human and nonhuman animal vaccines are very promising avenues for achieving this goal.

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Editor's Note
The case to which this commentary is a response was developed by the editorial staff.

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Dr Kaufman West reports being on the speakers bureau for AbbVie's hepatitis C virus medication, Mavyret.

The people and events in this case are fictional. Resemblance to real events or to names of people, living or dead, is entirely coincidental. The viewpoints expressed in this article are those of the author(s) and do not necessarily reflect the views and policies of the AMA.

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CASE AND COMMENTARY: PEER-REVIEWED ARTICLE

Bat-Borne Pathogens and Public Health in Rural African Artisanal Gold Mines

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Abstract
Marburg virus, the first filovirus discovered and a close cousin to the Ebola virus, is carried by the Egyptian rousette bat, a common cave-dwelling fruit bat endemic to sub-Saharan Africa whose populations can exceed 50 000 individuals. Community outbreaks of Marburg virus can result in high morbidity rates. In eastern Africa, favorite habitats of these bats include rural subterranean gold mines—sometimes worked illegally—that create environments conducive to zoonotic virus transmission. This commentary on a case describes how outbreaks of Marburg virus disease among people exposed to sub-Saharan African caves and mines containing these bats cause tensions among miners, companies, public health officials, and conservationists.

Case

In July 2007, 3 artisanal gold miners working in an African mine were diagnosed with Marburg virus disease (MVD),[1] a rare, often fatal hemorrhagic disease in humans caused by either Marburg virus (MARV) or Ravn virus (RAVV), the 2 marburgviruses in the genus *Marburgvirus*.[2] In past outbreaks of MVD involving multiple persons, case fatality ratios ranged from 23% (32 cases) to 90% (252 cases) and were typically propagated by human-to-human and nosocomial transmission (particularly through unsafe injection practices) following an initial spillover from the natural animal reservoir.[3] Soon after the outbreak was declared, the nation's health ministry, working with local district government administration, closed the mine indefinitely. Within weeks, a multinational team of disease ecologists, scientists, and conservationists, including experts from the host country, arrived to survey the fauna, primarily bats, where the miners had been working.

A months-long investigation identified the cave-dwelling Egyptian rousette bat (ERB) as the marburgvirus natural reservoir after the multinational team isolated both MARV and RAVV directly from ERB tissues and found that over 5% of the bats were actively infected.[4] Just after the ecology team departed—but while the mine was still closed—a local miner surreptitiously reentered the mine seeking gold and became nonfatally infected with RAVV. There were no further human infections resulting from this second spillover event.

For the next 9 months, the mine remained closed, with no clear plan for risk mitigation and no monetary compensation for local workers. The same disease ecology team returned to the mine the following May to inform local authorities of their initial findings and to conduct follow-up studies of the bats. At the mine, the team was met by agitated workers wanting to know when they could reenter the mine and resume their work. One miner pointedly asked why they were being "kept from their riches."

District health authorities and miners were informed that the ERBs were the source of infection and that, as long as the bats were present, the risk of contracting MVD would remain. They were also told that the bats should not be exterminated because they would likely return and that, without proper personal protective equipment—a costly and unsustainable investment for a local miner—workers could become infected. Miners and authorities were also told that the bats were vital to the ecosystem for seed dispersal and pollination, both of which are natural fruit bat activities vital to regional food production. During the following months, an extermination effort was nevertheless initiated by blocking egress from the cave with papyrus reed barriers and by restricting cave exits and capturing bats in fishing nets. As a result, bundles of dead and dying bats were discarded in a nearby forest, and shortly thereafter, no visible evidence of living ERBs remained in the mine.[5]

For the next 3 years, the mine was not monitored until an MVD outbreak emerged in a town within 20 km of the mine.[6] An investigative team returned to the mine and found that the papyrus reed barriers had long since disintegrated, the ERBs had returned, and there was clear evidence of renewed human activity inside the mine. Subsequent ecological studies found that the overall prevalence of active marburgvirus infection in the ERB population had surged to almost 3 times what it was previously.[5]

It was speculated that, after the initial bat culling, an immunologically naïve ERB population built up over time and marburgvirus was reintroduced and spread rapidly in the bat colony. The primary human case was never confirmed, but epidemiological investigations, combined with a spike in marburgvirus circulation levels in the bats, suggested renewed mining activity in the presence of ERBs as the most likely source of the outbreak.[5,6]

Commentary

This scenario involving rural African gold and other artisanal miners working in close proximity to bats known to carry high-consequence zoonotic pathogens highlights numerous ethically complex questions faced by public health professionals, wildlife conservation authorities, and workers with limited skill sets living in or near poverty.

One challenge is that mining gold and other minerals in remote areas of Africa (see Figure 1) offers an economic lifeline to local workers, with an additional lure of substantial monetary gain if significant gold deposits are found. A straightforward, although probably unrealistic, remedy to zoonotic disease transmission is to persuade miners to choose a different livelihood. But employment is limited in rural settings in many parts of Africa. Furthermore, some miners reported to us during our investigations that they had been working in the mine for many months or even years without knowingly contracting MVD. These reports suggested their belief that getting infected is not likely or that the virus is not real. It does not help that authorities charged with promoting public health or protecting wildlife are often spread thin and poorly resourced.

Figure 1. The Kitaka Mine in Uganda With an Air Compressor in the Foreground

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Exterminating the bats (see Figure 2) is also not a desirable solution for multiple reasons, primarily because mass culling to control zoonoses can make matters worse, as was shown by the marburgvirus resurgence at the Kitaka mine and by the resurgence of other bat-borne zoonotic diseases such as rabies in Peru.[7] Also, bats are very long-lived for small mammals, some living over 20 years in the wild,[8] and they will remember their ancestral homes if driven off and allowed to return.[9]

Figure 2. Egyptian Rousette Bats at Python Cave, Queen Elizabeth National Park, Uganda

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The scenario observed at the mine in Uganda is not unique. Almost a decade earlier, in northeastern Democratic Republic of Congo, MVD emerged among gold miners and their close contacts working illegally at another mine.[10] The outbreak lasted from 1998 to 2000 and was a consequence of many miners working underground with ERBs and other bats, sometimes for days at a time. Marburgviruses were detected in the bats, and genetic sequencing showed that the 2-year outbreak was really a series of multiple virus introductions followed by limited human-to-human transmission.[10,11] In fact, interviews and retrospective reviews of health records at a nearby hospital suggested that small clusters of MVD cases developed as far back as 1994.[10] The outbreak eventually ended when the mine flooded.[10]

Solutions

There are no easy answers to ethically relevant questions raised by cases like the one described. It is beyond the scope of this commentary to address some of these dilemmas, not least of which is basic food security, as ERBs and other bats are hunted for food in some regions of Africa.

Bat exclusion. A potential strategy that might be permanent is nonlethal exclusion of bats from caves using tight-fitting metal grates or other durable material. This strategy has been successful with small bats living in buildings,[12] but significant investment and regular monitoring by mine operators would be needed to ensure barriers' integrity in caves. For large commercial mining operations, nonlethal exclusion might be viable when it aligns with good corporate citizenship and helps to avoid costly litigation that could ensue from corporate failures to mitigate risks to workers from a known biological hazard.

Roost and forage site mapping. In Uganda and elsewhere, wildlife authorities are trying to identify ERB roost locations and map bats' nocturnal forage sites relative to human habitation locales.[13] Marburgviruses are shed in the saliva, urine, and feces of ERBs, and, being fruit bats, ERBs eat figs, mango, sweet banana, and papaya—foods popular among humans and other animals that ERBs could contaminate while they are feeding in the trees.[3] Data obtained from roost and forage site maps can help focus and enhance MVD surveillance efforts, especially when community health volunteers and facility health care workers are targeted for training in symptom recognition. Furthermore, as marburgvirus vaccines and medical counter measures are nearing approval by the US Food and Drug Administration and the World Health Organization, some having recently completed phase I trials,[14] these interventions could be made available at clinics near gold-mining communities. Infection prevention is best, but when spillover happens, rapid case identification and treatment availability are essential.

Tourist health. In addition to gold mining, tourism has been linked to spillover events. As shown in Figure 2, Queen Elizabeth National Park in Uganda is about 50 km from a mine[15] and attracts tourists interested in observing its rich biodiversity, including visible ERB colonies that attract predator snakes, such as pythons and forest cobras. To curb infection among tourists, the Ugandan Wildlife Authority built an enclosed viewing platform close to the cave. For over a decade now, tourists have been successfully and safely viewing the bats and snakes, allowing the ERBs to remain a vital part of the ecosystem while still attracting much needed revenue for the national park.

Conclusion

This commentary has discussed ways in which companies and governments can pursue due diligence to mitigate ecological and human health risks posed by Marburg virus.

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CASE AND COMMENTARY

How Should Wet Market Practices Be Regulated to Curb Zoonotic Disease Transmission?

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Abstract
Consumption and trade of wild animals presents major zoonotic disease transmission risks. Policies that aim to limit these practices must balance environmental health against the fact that trade and consumption of wild animals are important sources of livelihood and food security for many people. This commentary on a case suggests how public health threats posed by the wild animal trade, wet markets, and bushmeat practices might guide policies and actions of relevant stakeholders. A One Health approach is offered to navigate competing interests and balance ethical concerns.

Case

Dr M is an official in the Ministry of Health preparing to meet health officials from neighboring areas to consider policy strategies for regulating regional live wild animal capture and trade and wet market and bushmeat practices. In the wake of such practices' roles in SARS-CoV-2, influenza, and Ebola virus transmission from nonhumans to humans,[1] health officials remain concerned that emerging pathogens from reservoir or vector species pose threats to individuals living in the Global South in under-resourced communities for whom practice changes could mean exacerbated poverty and food scarcity. Dr M and colleagues consider how to weigh risks and benefits of practice changes[2] and how quickly policies guiding key practice changes likely to mitigate zoonotic transmission should be enforced.

Commentary

Dr M is rightly concerned about the roles that the wild animal trade and wild animal consumption play in increasing the risk of emerging pathogens and the spread of zoonotic diseases. The rise in globalization, including encroachment on wildlife habitat and expanded trade and travel networks, has increasingly brought humans into contact with animals that serve as reservoirs for infectious diseases. In particular, the recent expansion of the global wildlife trade and consumption of wildlife, which brings humans into direct and indirect contact with wild animals, has created an unprecedented situation for the scale and speed of zoonotic pathogen movement.[3,4] It is estimated that up to 75% of all emerging infectious diseases are zoonotic and that nearly 72% of zoonotic diseases originate in wild animals.[3,5] Recent examples of zoonotic diseases include Ebola, bird flu, Mpox, and COVID-19.[4,5]

Because zoonotic diseases emerge at the human-animal-environment interface, it is widely thought that successful control measures require a One Health approach.[1,3,4,5,6] One Health recognizes that the health of humans, animals, and the environment are all interrelated and encourages collaboration among diverse stakeholders to improve public health.[6] With respect to reducing the risk of zoonotic disease transmission, a One Health approach entails collaboration among various authorities and agencies, including those responsible for human health, veterinary health, agriculture and food safety, wildlife management, forestry, and other environmental agencies.[1,6] Given Dr M and colleagues' need to balance public health and economic concerns, they should adopt a One Health approach as they determine their policy recommendations.

Scope of Policy

Dr M is considering policy recommendations for 3 specific aspects of the wildlife trade: (1) live wild animal capture and trade, (2) wet markets, and (3) bushmeat practices. Dr M hopefully recognizes that these aspects of the wildlife trade are distinct and thus must be clearly defined so that specific policies can be designed and implemented for each.

Live wild animals captured and traded refer to those caught and sold *not* for consumption and those animals intended for consumption but not butchered until purchased at a wet market. While there is great diversity in the species of wild animals caught and traded, research suggests that only a few wild animal groups tend to host a high number of zoonotic pathogens.[7] Shivaprakash et al propose that policy designed to mitigate zoonotic disease transmission from wild animals should focus on preventing the trade of animal groups with high pathogenic load, specifically "rodents, bats, primates, ungulates, carnivores, and marsupials."[7]

Lin et al distinguish animal markets along 3 dimensions: live-animal markets, wildlife markets, and wet markets.[8] Live-animal markets include those selling live domesticated animals and live wild animals for both consumption and non-consumption. Wildlife markets concentrate only on the trade of wild animals, which may be either alive or dead, and may be intended for either consumption or non-consumption. Like the wildlife trade itself, wet markets are incredibly diverse, ranging in size, products offered, and level of legal and regulatory oversight. Wet markets, named for their frequently wet floors due to the washing of stalls to keep them clean and "the melting of the ice used to keep foods fresh," can range from markets "selling just fruits and vegetables, to those selling wild-caught (and possibly endangered) wildlife"—that may be alive or dead and domesticated or wild—for consumption.[8] Lin et al identify 6 key characteristics of animal wet markets that increase the risk of zoonotic disease transmission: animal taxa at high risk of being disease carriers, the presence of live wild animals, poor hygiene practices by vendors, larger markets that serve larger numbers of people, high animal density and interspecies mixing, and lengthy supply chains.[8]

Bushmeat practices refer to the harvesting of wild animals, legally or illegally, for consumption. Mammals make up the majority of animals harvested as bushmeat in terms of both number and biomass, with ungulates and rodents being most common.[2] Much of the urban bushmeat trade occurs in open markets, although a substantial amount of bushmeat also passes through more informal channels. While this demand is often driven by wealthy individuals who view bushmeat as a luxury item, in poorer rural areas around the world there are also many people who rely on bushmeat for their livelihood as well as for food security.[2,8]

Hilderink and Winter identify 4 phases of the wildlife trade wherein risks of zoonotic spillover emerge: (1) hunting, trapping, and butchering; (2) transportation; (3) sale; and (4) consumption and use. They explain: "Given that those zoonotic pathogens spread through various transmission pathways, sometimes multiple pathways at the same time, e.g., through (in)direct physical contact, bodily fluids, and faecal-oral, foodborne, and airborne transmission, a single trade activity can have a drastic impact on the spread and amplification of zoonoses."[3] Dr M and other policy makers thus need to recognize the importance of regulation at each phase of the wildlife trade, from capture to consumption, while at the same time taking into account the ways this trade supports the livelihoods and nourishment of many individuals. The One Health approach that Dr M and colleagues should embrace must also engage all relevant stakeholders to ensure that policies are put in place that focus not only on prevention of disease transmission but also on equity.

Reducing Zoonotic Transmission Risk

Given the fact that the wild animal trade, like zoonotic disease emergence and transmission, exists in a diverse range of settings, it is clear that generalized one-size-fits-all policies will not be effective interventions.[9] In the wake of the COVID-19 outbreak, for example, there were calls for outright bans of wet markets, but such extreme measures are generally regarded by experts as misguided.[10] Bans are difficult to enforce and tend to drive the sale of wild animal products underground where they are harder to monitor and regulate.[9,11] Instead, there is general agreement that policies to intensify regulation, monitoring, and enforcement work better to reduce health risks associated with demand for and consumption of wild animals.[10]

As Dr M and colleagues weigh the risks and benefits of policies for regulating live wild animal capture and trade, wet markets, and bushmeat practices, they will need to consider the various phases of the wildlife trade and types of wet markets and recognize that a variety of different policies will be needed due to the complex and dynamic nature of the wild animal trade. These policies should include those that target individuals through educational campaigns, engage communities in conservation efforts, and improve sanitation and oversight of the trade and sale of wild animals, as well as policies directed at the national and international level to improve zoonotic disease surveillance and reduce the risk of zoonosis from the international wildlife trade. This work will require collaboration among a variety of authorities, agencies, and stakeholders, both within and across countries.

Public health campaigns targeting individuals should be developed to educate people about zoonotic diseases and the dangers of consuming meat from wild animals and to educate and train those who work within the wild animal trade in proper food safety and sanitation.[3,7,11] Conservation and community-outreach programs should be developed both to reduce interactions at the human-wildlife interface and to ensure that such measures are implemented in an equitable manner that balances ecological and biodiversity conservation with food security and the support of community livelihoods.[2,3] Effective efforts include creating protected areas or land sharing, agroforestry practices, and alternative livelihood opportunities to the wild animal trade, such as ecotourism, community-led anti-poaching, or wildlife stewardship efforts.[2,3]

Government policies that target transportation and sale of wild animals should focus on sanitation and oversight and should likely include stringent hygiene standards in traditional food markets, regular ante- and postmortem inspections at the time of slaughter, separate hygienic areas for slaughter and dressing that are away from the public and other live animals, regulations to prevent species mixing and reduce overcrowding, surveillance for early detection of disease, and monitoring of zoonotic disease in import and export animals and of food processing facilities and employees.[3,5,6,7,12]

Government policy should also focus on reducing global wild meat consumption. While targeted bans on animals most likely to be zoonotic disease vectors have been proposed as alternatives to general bans, even selective bans are likely to drive trade underground.[8,11] An alternative to targeted bans might be targeted restrictions. For example, one 2020 modeling study found that increased international restrictions on the trade of wild animals resulted in a decrease in the estimated volume of animals traded and thus a decrease in the estimated volume of potential zoonotic disease transported.[4] A crucial element in limiting zoonotic disease transmission, however, is development of an international metagenomic pathogen discovery and surveillance system to identify new and emerging diseases.[5,7]

Policy makers like Dr M need to develop strategies that are heterogeneous, local, and created in consultation with local communities.[3,8] An example of such a strategy might be targeted bans of high-risk animals but only within large, urban wet markets, thereby creating greater flexibility for those whose livelihoods depend on the rural bushmeat trade.

Balance

In general, policy makers such as Dr M and colleagues should focus on minimizing harmful disruptions to communities while prioritizing regulating markets that trade in wild animals, which pose the greatest risk of zoonotic disease transmission.[8] Reducing the risk of zoonotic disease transmission that the wild animal market engenders will require a cooperative One Health approach that brings together wildlife experts, national and international legislators, conservation organizations, and communities and will require coordinated surveillance at all levels, local to international.[3,6] It is important to recognize that these policy improvements will be costly and that developing countries will likely need financial assistance. Dr M and colleagues will thus need to discuss the economic feasibility of such policies and secure funding to ensure that the development of policies and programs is done equitably for individuals and countries.

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The people and events in this case are fictional. Resemblance to real events or to names of people, living or dead, is entirely coincidental. The viewpoints expressed in this article are those of the author(s) and do not necessarily reflect the views and policies of the AMA.

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MEDICAL EDUCATION: PEER-REVIEWED ARTICLE

Five Things Clinicians Need to Know About Zoonotic Viral Spillover and Spillback

Gregory C. Gray, MD, MPH, Laura A. Pulscher, PhD, MSc, and Hisham O. Alsharif, MBBS

Abstract
Since the 1990s, multiple infectious diseases have "spilled over" from nonhuman animals to infect humans and cause significant global morbidity and mortality. Despite efforts to detect and respond to such threats, surveillance and mitigation efforts have been criticized as ineffective. This article describes what "spillover" and "spillback" events are and canvasses 5 ways in which clinicians can improve emerging microbial pathogen, especially viral, detection and containment responses.

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Viral Zoonoses

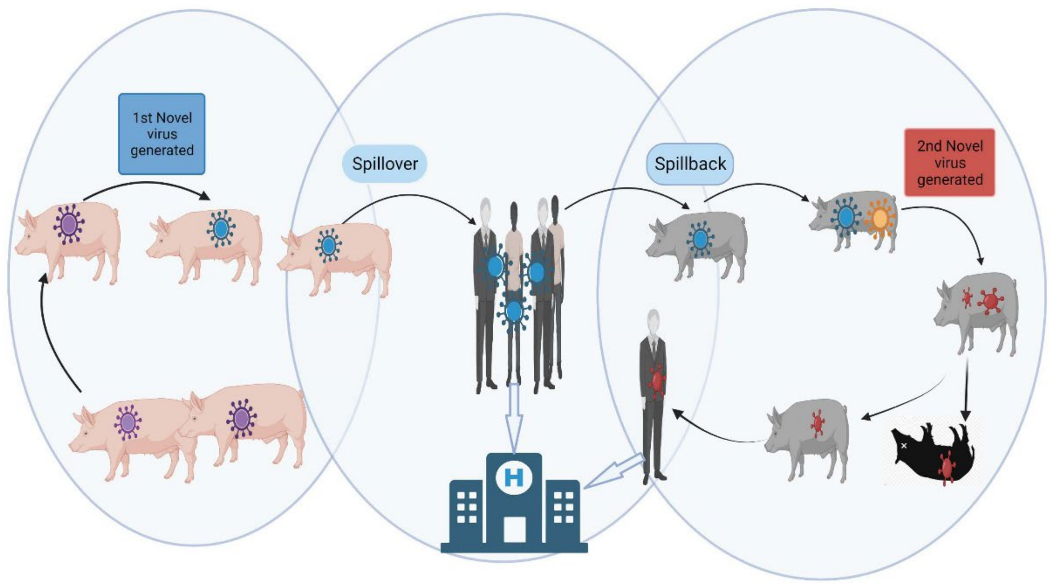
During the last 25 years, it has been painfully evident that modern medicine, despite all its remarkable advances, is woefully unprepared for epidemic threats, especially viral zoonotic threats.[1,2] One need only examine the recent human morbidity from epidemics of West Nile virus (2002-present),[3] SARS-CoV-1 (2002-2003),[4] Marburg virus (2004-2005),[5] H1N1 influenza A pandemic virus (2009-2010),[6] MERS-CoV (2012-2019),[7] H7N9 avian influenza virus (2017),[8] ebolavirus (2013-2016),[9] Zika virus (2013-17),[10] yellow fever virus (2016-2017),[11] Lassa virus (2018),[12] and SARS-CoV-2 (2019-present)[13] to affirm this position. Part of the difficulty in preventing such zoonotic viral epidemics is a lack of understanding of the nature of these threats. Here, we summarize observations on zoonotic viral spillover and spillback that we believe every clinician should know. Having this knowledge will aid clinicians in sounding a public health alarm should they be among the first to witness a new zoonotic emerging infectious disease problem.

Definitions

The following concepts are key to understanding the nature and scope of zoonotic threats.

- *Infection*. Porta et al define infection as “the entry and development or multiplication of an infectious agent in an organism, including the body of humans and animals.”[14] Infections do not always cause signs and symptoms of disease.
- *Zoonosis*. Any disease that can be transmitted from nonhuman animals to humans, or from humans to nonhuman animals (reverse zoonosis).[15]
- *Emerging infection disease*. An infectious disease that has newly appeared in a population or has existed previously but is rapidly spreading in terms of either the number of people infected or the geographical areas affected.[16]
- *Spillover*. Microbe transmission “from one species (usually the reservoir but potentially an amplifying or bridge host) to a novel, susceptible species, establishing infection in this individual new host”[17] (see Figure 1).
- *Spillback*. A specific case of spillover when a microbe spills from a new host back to the original host (see Figure 1).[17]
- *One Health*. The Association Veterinary Medical Association defines One Health as “The integrative effort of multiple disciplines working locally, nationally, and globally to attain optimal health for people, animals, and the environment.”[18]

Figure 1. Virus Spillover and Spillback



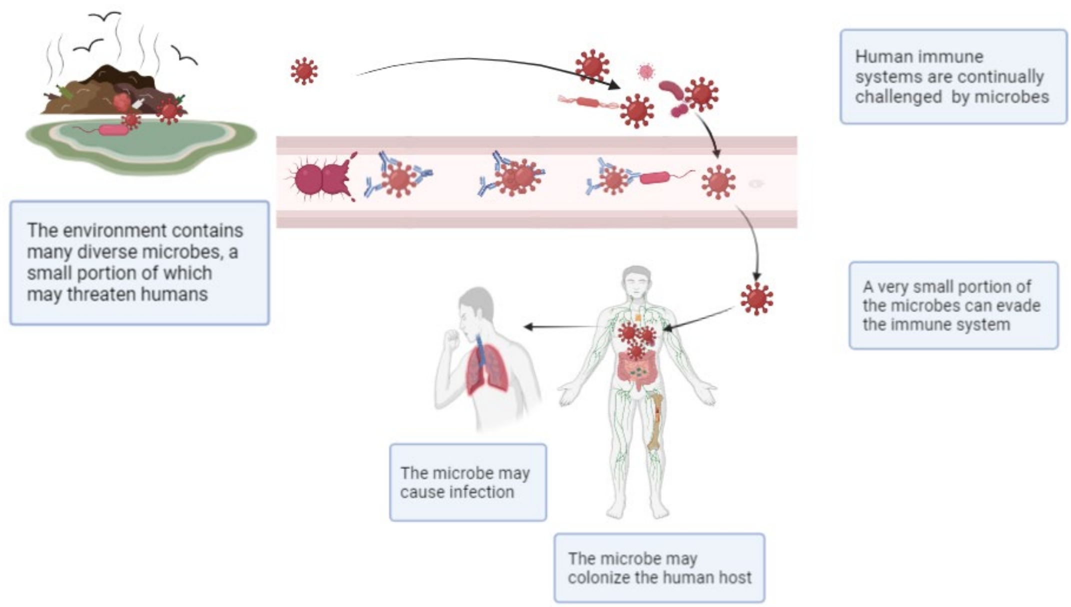
Created with BioRender.com.
Abbreviation: H, human hospital.
A novel virus (blue virus) emerges in pigs and is transmitted to humans in a spillover event. This virus is amplified in humans and spills back to another group of pigs. In this second group of pigs, the virus mixes with other swine viruses and changes yet again (red virus). This new virus has the potential to cause new morbidity in both pigs and humans.

Lesson 1: Viruses Are Everywhere

We are continually challenged by viruses from both outside and within our bodies. Viruses of many kinds surround and threaten us, yet relatively few have the capacity to cause disease (see Figure 2). Exact counts of unique viruses or measurements of total viral mass are not available, but it is agreed that viruses greatly outnumber bacteria and that viruses can infect all forms of life, including bacteria and single cell organisms. It has been estimated that there are more than 10 nonillion (10^{30}) individual virus particles on earth,[19,20] which is said to exceed the number of stars in the universe.[21]

Scientists have estimated that each of us harbors more than 380 trillion individual viruses living on or inside our bodies,[22] most of which do no harm. These difficult-to-comprehend figures are tempered somewhat when one recognizes that a high proportion of viruses in these estimates are copies of the same virus. Nevertheless, estimations of counts of unique viruses are also astounding. For instance, considering just mammals alone, it has been estimated that the earth currently has 5291 unique species of mammals, which in total harbor roughly 40 000 unique species of viruses.[23] Approximately 10 000 of these viral species are thought to have potential to cause illness in humans (ie, they are zoonotic).[23] Given the large number of diverse viral threats both outside and within a human host, one should marvel that our human immune systems are so effective in preventing viral disease.

Figure 2. The Human Immune System Prevents Most Microbial Assaults From Causing Infection



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Humans live in environments that contain trillions of microbes. Our bodies are extremely effective in preventing infections from the vast majority of these microbes. Nevertheless, a small percentage of these microbes can invade our body and cause disease.

Lesson 2: Extant Medical Diagnostics Can Miss Clinically Important Viral Infections
Modern viral diagnostics are finely tuned to be both sensitive and specific with respect to previously recognized viral pathogens. When previously recognized viruses change or never-before-detected viruses emerge to cause disease, they are often missed by routine clinical diagnostics, as illustrated recently by delays incurred in developing and making widely available viral diagnostics for the A/(H1N1)pdm09 virus[24] and some novel emergent coronaviruses. Fortunately, modern laboratory diagnostic science is reducing these delays. For instance, in 2003, it took approximately 5 months for the newly emergent SARS-CoV-1 to be identified and sequenced, such that molecular diagnostics could be developed.[25] In contrast, in 2019, SARS-CoV-2 was sequenced approximately 3 weeks after visualization with electron microscopy.[25] Nevertheless, in January and February 2020, 6 European laboratories reported delays of up to 2 weeks in implementing molecular diagnostics for SARS-CoV-2 due to contaminated material,[26]

and by June 2020, these diagnostics were still not widely available in low- and middle-income countries in Africa and South Asia.[27] Hence, clinicians are wise to recognize that a negative clinical diagnostic assay—even a multiplex molecular assay—does not necessarily rule out infection from a targeted virus that has changed or a never-before-characterized virus.

Lesson 3: All Viral Spillovers Are Not the Same

In a 2018 report, Carroll et al estimated that there were 1.67 million as-yet-undiscovered viruses in mammal and bird hosts.[28] As much of the microbial world is yet to be discovered, we need to develop tools to make those discoveries, especially for microbes that have just spilled over to infect humans but are not yet efficient in causing human-to-human transmission.[29] Detecting a pathogen in early spillover and mitigating transmission before it further adapts to humans could prevent human epidemics.[29,30] Special surveillance strategies and special broad diagnostic approaches are needed to pick up such viruses before they become problematic.

As there are many possible viral threats, it would be strategic to focus on viruses with the greatest spillover risk to humans. However, rates of virus spillover and spillback are largely unknowable because the vast majority of occurrences are dead-end events.[31] Moreover, many zoonotic virus infections might not cause signs or symptoms of disease. Nonetheless, scientific teams have conducted retrospective studies of the small proportion of detected spillover events and have attempted to establish spillover risk scores for specific viruses. One such modeling team has developed a rather compelling ranking system (SpillOver platform) for animal viruses; risk factors were identified on the basis of expert opinion as well as an examination of the limited scientific evidence.[32] In ranking the spillover potential of 887 wildlife viruses, Grange et al observed that their model identified 12 known zoonotic wildlife viruses, including SARS-CoV-2, but also ranked a number of other wildlife viruses as having high spillover risk that had not previously been observed to infect humans.[32] However, in their critique of this analysis, Wille et al recently argued: "we demonstrate that the virological data on which these analyses are conducted are incomplete, biased, and rapidly changing with ongoing virus discovery."[33] Given these data deficiencies, other groups rely more on expert opinion in evaluating the limited available data and in ranking viruses for risk of either spillover or the generation of human epidemics. For instance, the World Health Organization is ambitiously assembling 20 to 25 groups of experts to review and prioritize viruses in numerous viral families for their epidemic and pandemic risk.[34]

Such data-centric and expert panel reviews have generated considerable debate on how best to conduct surveillance of spillover- and spillback-prone viruses. Some scientists have embraced a broad viral discovery approach with a central focus on studying the genetic characteristics of wildlife viruses.[28] Other scientists argue that surveillance would be better focused on performing One Health-related studies in geographical areas of previous emerging infectious disease risk where humans are in close contact with dense populations of animals.[2,29,30,35,36,37] For example, the first author (GCG) and colleagues were fortunate to partner with Chinese scholars in simultaneously studying Chinese pig workers, pigs, and pig farms for evidence of influenza A virus spillover from pigs to humans. We found that immunologically naïve swine workers had markedly increased risk of infection with swine influenza viruses.[38]

Whatever the logic, many experts agree that surveillance tools should focus on detecting novel viruses from families of viruses at risk of spilling over to humans and causing disease and subsequent epidemics. Some argue, like the first author (GCG) and colleagues' research team, that respiratory viruses are the highest priority because they spread rapidly and are difficult to control.[29,36,39] A number of viral families have a history of causing respiratory disease epidemics: *Orthomyxoviridae* (contains influenza viruses), *Coronaviridae* (contains coronaviruses), and *Paramyxoviridae* (contains parainfluenza viruses).[29,36,40] To these we add *Adenoviridae* (contains adenoviruses), *Pneumoviridae* (contains respiratory syncytial virus and human metapneumovirus) and *Picornaviridae* (contains enteroviruses and rhinoviruses), as each of these viral families has been responsible for additional human respiratory virus epidemics.[39] Other short lists of important human-disease-causing viral families include *Bunyavirales* (contains hantavirus), *Filoviridae* (contains ebolavirus), *Flaviviridae* (contains dengue and yellow fever viruses), and *Togaviridae* (contains Sindbid virus).[40,41] Recently, Valero-Rello and Sanjuan studied a database of 12 888 virus-host associations (comprising 5149 viruses and 1599 host species) and concluded that enveloped viruses are more likely to spill over to new species.[42] No matter the specific viral families included in novel virus surveillance efforts, better viral discovery diagnostics are needed to detect specific viral spillover threats within these viral families such that future human epidemics could be averted.

With awareness that spillover events are not homogeneous, clinicians can help detect spillover events by being vigilant and considering novel zoonotic spillover as a possible cause of unusual signs and symptoms in their patients, especially those with intense occupational exposure to animals. Simply asking the question, "Could my patient be suffering a spillover or spillback novel virus infection?" could be the first step in novel virus discovery.

Lesson 4: Viral Spillback Is a Global and Domestic Public Health Threat

Zoonotic viruses that cause disease in humans can spill over to other animal populations, mutate or recombine, and spill back to humans, causing additional disease outbreaks. While the movement of the A/(H1N1)pdm09 virus from humans to various animal species, especially pigs, has caused considerable alarm,[15,43] it is the generation of novel variants of SARS-CoV-2 in these new animal hosts that is of most concern. As of August 23, 2023, human-adapted SARS-CoV-2 had infected at least 34 unique animal species in 39 countries.[44,45] Current evidence suggests that SARS-CoV-2 has adapted to new mink and white tail deer hosts and at least some mink-associated novel variants are capable of spilling back to humans.[46] Although current evidence suggests that pigs[47,48,49,50,51,52,53] and cattle[54,55,56] are not routinely susceptible to infection with circulating strains of SAR-CoV-2, were SARS-CoV-2 strains to adapt to infect livestock, other circulating strains of enzootic coronaviruses in livestock might increase the risk of novel virus generation through recombination. When confronted with a patient with unexplained illness and negative diagnostic tests, clinicians are wise to ask questions about a patient's exposure to animals and to consider animal pathogen involvement in the patient's signs and symptoms.

Lesson 5: Clinicians Have Obligations to Be Knowledgeable, Vigilant Agents of Detection

We currently only detect a small proportion of spillover events, and often, when we do, it is too late to take public health action. We need to adopt strategies to detect spillover events when and where they arise. Clinicians need to be vigilant and engage public health officials (locally, regionally, and, if necessary, through national or international reporting networks such as PROMED[57] and GOARN[58]) when they have suspicions that the populations they serve might be experiencing spillover or spillback events. While one might argue that the A/(H1N1)pdm09 virus and SARS-CoV-2 spread so rapidly and efficiently that early warning would not have made much of a difference, other spillover events might be more amenable to public health intervention, as the majority of spillover viruses need considerable time to circumvent numerous immunologic barriers[36] to fully adapt to their new human host.[29] Recently, G.C.G. and colleagues[49] and other research teams[59,60] detected novel animal coronaviruses among humans with acute respiratory disease in several geographical areas.[61] It seems likely that these spillover viruses have not yet sufficiently adapted to their new human hosts to cause efficient human-to-human transmission. Such viral detections afford opportunity for the development of targeted molecular diagnostics to ascertain viral ecology and stop virus transmission. Given appropriate pan-species diagnostics,[29,62] a vigilant health care professional might sound an early alarm and engage public health authorities, who might then take measures to mitigate the threat before the virus has fully adapted to humans.

Responding to International and National Vulnerability

Recent epidemics have demonstrated how novel zoonotic respiratory viruses can cause widespread human infections. We have reviewed the important concepts of zoonotic virus spillover and spillback, seeking to inform clinicians of the important roles they may play in detecting novel viruses and helping to reduce such viruses' spread.

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MEDICAL EDUCATION: PEER-REVIEWED ARTICLE

Top 5 Things Health Professions Students Should Know About Ecology and Waste Management

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Abstract
The environments in which we live affect individual and community risk for disease transmission and illness severity. Communities' and neighborhoods' waste stream management designs and health care organizations' spatial and structural architecture also influence individuals' and communities' pathogenic vulnerabilities and how well health sector industrial hygiene practices support them. This article describes a One Health approach to planetary environmental health and suggests strategies for implementing a One Health or Planetary Health approach in the context of climate change.

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Introduction

The health care industry is a major contributor to environmental degradation through the generation of waste and greenhouse gas emissions.[1,2,3] Health care professionals have a responsibility not only to manage the health consequences of our current environmental crisis (eg, food-, water-, and vector-borne diseases), but also to minimize ongoing contributions of the health care industry to that crisis. To lean into this challenge, health care professionals should understand the sources and health impacts of plastic waste and wastewater and factors that exacerbate or alleviate environmental health threats, such as climate change and the built environment. Climate change, in particular, is intensifying these threats and the health inequities rooted in poverty and insanitary living conditions.[4] Systems-based approaches, such as those offered by One Health or Planetary Health, can be applied to local disease ecology worldwide to improve both local and global public health. This article describes a One Health approach to planetary environmental health and suggests strategies for implementing such an approach in the context of climate change.

Plastic Waste
A significant global issue is the pollution crisis, especially plastic waste, which harms both the environment and human health. The problem of plastic waste is particularly acute in low-income countries with inadequate waste management systems and policy regulation. Non-biodegradable plastic waste leads to blockage of drainage systems and accumulation in landfills, oceans, and other natural habitats, contributing to ecosystem degradation and biodiversity loss.[5,6] Plastics also enter the food chain in the form of microplastics and ultimately end up in our bodies; the accumulation of microplastics in the digestive tract may be linked to negative health effects, including alteration of the gut microbiome and increased risk of colon cancer.[7,8] The breakdown of plastics and other household waste, either in landfills or by burning, also releases toxic chemicals that contaminate soil, ground and surface water, and air. These toxic chemicals also cause harm to the central nervous system and the respiratory and cardiac systems and interfere with hormone function, causing developmental and reproductive problems in both humans and wildlife.[9,10] Furthermore, burning plastic waste not only contributes to air pollution but also results in greenhouse gas emissions that contribute to climate change, causing both direct and indirect harm to human health.[11]

Local management of plastic pollution is only part of the solution to planetary environmental health. Addressing plastic pollution at large is vital to protecting both the environment and public health, and reducing the further generation of plastic waste is a global responsibility. A sizeable proportion of US health care waste is unrecycled plastic,[12] and, as such all health care professionals should contribute to shifting the medical system to more sustainable practices.

Wastewater
Wastewater infrastructure plays 2 major roles: removal of feces and buffering of rainwater. The impacts of inadequate water infrastructure are far-reaching. It is a major risk factor for diarrheal disease,[13] one of the leading causes of pediatric death worldwide.[14] While people often think about access to clean drinking water as key to preventing diarrheal disease, the removal of wastewater is just as important to preventing environmental contamination with diarrheal pathogens and intestinal helminths.[15] Fecal contamination of soil perpetuates the cycles of ascariasis, strongyloidiasis, and hookworm infections. Inadequate wastewater infrastructure leads to contamination of surface water and groundwater; this contaminated water can leach into wells and piped water systems or end up in agricultural irrigation water.[16,17,18] Often less considered are the myriad nondiarrheal diseases that can be spread by inadequate water infrastructure. For example, inadequate storm drainage and consequent flooding can increase the risk of not only diarrheal diseases but also mosquito-borne infections, leptospirosis, snake bites, and injuries.[19]

Health care facilities generate some of the most high-risk wastewater. Hospital wastewater from sewage sources is a risk not only for pathogens broadly but also for highly antibiotic resistant microorganisms, pharmaceutically active compounds, detergents, and other chemical and organic toxins.[20] Indeed, the biodegradability index of hospital wastewater is lower than that of municipal wastewater.[21,22,23] Additionally, hospital wastewater composition and treatment varies by place, and many treatments do not completely eliminate antibiotic-resistant microorganisms, viruses, or other organic and chemical pollutants.[24] In addition to following facility-wide wastewater management protocols, each medical department can contribute to identifying less toxic replacement products wherever possible.

Architecture and Built Environments

Architecture plays a key role when it comes to environmental and human health and has the potential to promote well-being or increase disease risk. The built environment has broad impacts on health that range from infectious disease risk to poor mental health, air pollution, and heat exposure. For instance, the risk of vector-borne diseases, such as chagas disease (spread by triatomine bugs), dengue fever (spread by *Aedes aegypti* mosquitoes), and malaria (spread by *Anopheles* mosquitoes) are mediated by house construction and landscaping features. Better house construction materials have been associated with decreased infestation with triatomine bugs,[25] just as air conditioning and building materials that promote ventilation and window screens that create barriers for mosquito entry can decrease risk of dengue fever and malaria.[26,27,28] Landscape features outside the house also play an important role in mosquito abundance. The presence of containers that hold rainwater or gutters on houses create ideal breeding sites for *Aedes Aegypti* mosquitoes,[29] which also increase in places with shade, such as house eaves or cover from trees in the yard.[30,31] Similarly, stagnant pools of water provide breeding sites for *Anopheles* mosquitoes.[32]

In addition to influencing the spread of vector-borne infectious diseases, the built environment plays a critical role in exposure to animals—and thereby zoonotic diseases—as well as diarrheal diseases, as discussed above, and other health conditions.[33,34] Urban design and housing construction have been linked to cardiorespiratory and metabolic diseases.[33,34] The built environment also affects mental health and overall well-being.[35] Hazardous construction materials and residential proximity to industries generating toxic pollutants can have a multitude of negative health effects, such as hematologic and respiratory impacts of benzene exposure.[36,37,38]

Health care professionals have the opportunity to collaborate with ecologists, architects, urban planners, and policy makers to design and advocate for construction of a healthy built environment. By understanding how the built environment affects disease risk, health care professionals can engage with public policy makers, urban planners, and engineers to build healthier communities. Furthermore, the built environment in and around the hospital is critical to promoting well-being for the most sick and vulnerable people in the community. The importance of a resilient hospital built environment has never been as important as it is today, with increasing extreme weather events placing even greater strain on health care systems. Preventive medicine thus goes beyond diet, exercise, and health screenings: it entails building resiliency and an all-hazards approach to disaster planning into health care systems.

Climate as an Ecological Health Determinant

Climate change poses the most significant threat to public health[39] and compounds the waste problem in many ways. For instance, the problem of marine food insecurity from pollution is exacerbated by the effects of climate change on oceans, including ocean acidification and deoxygenation, which is resulting in unprecedented loss of marine biodiversity and abundance.[40] *Aedes aegypti* mosquitoes, which breed in discarded plastic waste, are highly adapted to hot temperatures and therefore their suitable habitat range is rapidly expanding and is projected to include 91% of the US population by 2100.[41] Increasing extreme weather events have also been associated with amplification of vector-borne, zoonotic, and diarrheal diseases. For example, drought increases water insecurity, resulting in increased use of water storage containers that provide breeding grounds for *Aedes aegypti* mosquitoes.[42] Drought also amplifies interspecies contact and thereby transmission between animals, vectors, and humans, as recently proposed as a trigger for an unusual yellow fever virus outbreak in Brazil.[43] At the opposite extreme, flooding can increase contact with water contaminated by rat or dog urine in places with poor trash and water management, increasing the spread of leptospirosis; flooding also overwhelms wastewater systems and exposes people to feces-contaminated water.[44,45] Extreme weather events, including flooding and heat waves, are also associated with mood disorders and cardiovascular events.[46,47]

Again, health care providers have an important role not only in the management of these impacts, but also in urgently decreasing emissions that are driving climate change. The US health care system alone is responsible for approximately 4.5% of global greenhouse gas emissions, and despite the importance of mitigating climate change to improve health, it has lagged behind other industries in reducing emissions.[48] Health care providers and professionals have a responsibility and opportunity to mitigate climate change by advocating for and making choices to get to net zero—by improving preventive care, investing in clean energy, and selecting environmentally conscious supplies.[49]

A Planetary Ecological Approach

One Health is a long-standing approach to public health in which the health of the collective communities of humans, animals, and the environment is assessed simultaneously in recognition of their interdependence. Historically, One Health has focused on zoonotic infectious diseases, with physicians, veterinarians, and ecologists working closely together.[50] A classic example is leptospirosis, a bacterial infection that can cause severe, life-threatening disease in humans. Leptospirosis is transmitted to humans by physical contact with water that has been contaminated by the urine or feces of an infected animal, often rats or stray dogs.[51,52] Trash in or around a community increases the abundance of these animals, thereby increasing the risk of leptospirosis, particularly in communities that are also prone to flooding. In addition to flooding, which is increasing with climate change, trash accumulation and the rise of informal urban settlements promote the spread of this disease.[53]

The One Health approach has expanded beyond zoonotic disease in recent years, given the increasing recognition of the plethora of connections between human health and the environment. The evolution and expansion of the One Health approach is now often termed Planetary Health and incorporates research on climate change and social determinants of health.[54] Planetary Health also incorporates environmental health, including waste, and its relation to human health. Microplastics invade the food chain and are increasingly recognized as a problem for both animals and humans.[55,56] Pollution on land and in the oceans negatively impacts our food supply and increases food insecurity.[55,56,57,58] Research shows that increased mental health stress is associated with residential areas having an abundance of trash and, conversely, that well-being is associated with local green space.[59,60] Taking a One Health or Planetary Health approach to health problems can improve health care professionals' early recognition of environmental health risk factors and promote health at the community and individual levels.

Conclusion

Waste management, the built environment, and climate change are intricately connected and shape environmental risk for many health issues. These risks are often compounded and disproportionately affect the most vulnerable populations. Understanding the interaction between health and ecology provides an opportunity to improve public health both locally and globally. For health professionals, this opportunity extends beyond identifying individual patient risk factors; individual efforts related to waste management, the built environment, and climate change can help minimize the widening inequities in population health. In particular, health professionals' responsibility to advocate for patients' health includes raising the specter of climate change, plastic pollution, and waste management as a critical health threat that demands radical mitigation. By taking a planetary health approach and collaborating with specialists from other disciplines—for instance, with veterinarians, ecologists, policy makers, urban planners, and local community advocates—health professionals can help to build a world that reduces the impact of the climate crisis on humans and our environment. Much of this work needs to look inwards—at the environmental, and therefore health consequences, of the waste and greenhouse emissions generated within the health care industry.

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AMA CODE SAYS

AMA *Code of Medical Ethics'* Opinions Related to Health Ecology and Disease Transmission

Maya Roytman

Abstract
The AMA *Code of Medical Ethics* focuses primarily on physician responsibilities and obligations in the context of patient-physician and community-physician relationships. Nevertheless, key principles outlined in the AMA *Code* facilitate understanding of complex relationships among humans, nonhuman animals, and our ecosystem and offer guidance for both clinicians and professional bodies on changing ecological factors that impact individual health.

One Health in Practice

Since the onset of the COVID-19 pandemic, health professions communities have paid more attention to health ecology and One Health approaches to controlling infectious disease transmission. One Health has been defined as "the collaborative effort of multiple disciplines—working locally, nationally, and globally—to *attain optimal health* for people, animals and our environment."[1] Although One Health has been operationalized in medical spaces through an anthropocentric lens for the promotion of human health, it is important to note that each facet of the interdependent, triadic relationship between human, animal, and environmental health warrants moral consideration in its own right.[2,3] Because of the importance of this relationship for human health,[4] ecological influences on health are of heightened ethical concern and value to the American Medical Association's (AMA's) mission of promoting "the art and science of medicine and the betterment of public health."[5] The AMA *Code of Medical Ethics* outlines some of these considerations in relation to infectious disease transmission risk and prevention.

Zoonotic Transmission

Nonhuman to human animal disease transmission, known as zoonotic transmission, has heightened the threat to human well-being, as climate change and antimicrobial resistance increase risk of zoonosis.[6,7] Zoonotic pathogens often mutate in ways that increase risk of transmission; notable examples of this phenomenon include the influenza, SARS, COVID-19, and Ebola viruses.[8,9,10] Furthermore, current food system practices, such as factory farming, also increase the likelihood of zoonotic disease transmission.[11,12] Thus, physicians should learn about and acknowledge ecological impacts on human health in order to better serve patients whose health has been compromised by zoonotic and environmentally influenced diseases.

Minimization of zoonotic disease transmission begins with clinician well-being. Opinion 9.3.1, "Physician Health and Wellness," specifies that physicians should take "appropriate measures to protect patients, including measures to minimize the risk of transmitting infectious disease commensurate with the seriousness of the disease,"[13] which should include physicians taking precautionary measures when traveling to areas experiencing a zoonotic outbreak. Should such an ecologically induced infection pose harm to patients and other clinical team personnel, steps must be taken to minimize transmission from an infected clinician or animal reservoir as much as possible. These steps can be extrapolated from Opinion 8.4, "Ethical Use of Quarantine and Isolation,"[14] and Opinion 8.7, "Routine Universal Immunization of Physicians,"[15] the former of which stipulates that "appropriate protective and preventive measures to minimize transmission of infectious disease from physician to patient, including accepting immunization for vaccine-preventable disease," should be taken when such vaccines are available, safe, and effective.[14] The burden of preventing transmission of and containing infectious diseases falls upon health care organizations, which "have a responsibility to proactively develop policies and procedures for responding to epidemic or pandemic disease with input from practicing physicians, institutional leadership, and appropriate specialists."[5]

Medical Tourism and Xenotransplantation

Medical tourism—ie, travel abroad to seek medical care—increases the risk of global transmission of infectious and even zoonotic diseases. Not only is follow-up care difficult for medical tourists, but travelers who acquire zoonotic or vector-borne diseases abroad that are not endemic to their home countries may contribute to those diseases' widespread transmission.[16] Opinion 1.2.13, "Medical Tourism," speaks to some of these ethical considerations, stating that medical tourists may "face heightened travel-related risks" and "may pose public health risks to their home communities."[17] As medicine becomes more globalized and medical tourism becomes more common, oversight and regulation of screening and vaccination of travelers domestically and internationally ought to be a priority.

Xenotransplantation, which is "using organs or tissues from nonhuman animal species for transplantation into human patients," has become a novel method for addressing the shortage of transplantable organs.[18] As such, the AMA *Code* specifies in Opinion 6.3.1, "Xenotransplantation," that participants in xenotransplantation clinical research studies should be "informed about and consent to the unique risks and burdens" of the procedure, which could include novel infectious diseases or zoonoses and the need for lifelong surveillance.[18] Additionally, considerations of patient safety and public health with regard to xenotransplantation are important to ensure dignity of care and humane treatment of animals involved in this procedure. Further research on more sustainable options for organ transplantation that prioritize these considerations through a One Health framework should be pursued.

Ecological Relationships

Opinion 8.11, "Health Promotion and Preventive Care," states that physicians have a "professional commitment to the health of patients and the public."[19] By applying One Health and health ecology frameworks, physicians can fulfill their obligation to promote the health of the community by, for example, collaborating with epidemiologists or other public health officials to map cases of zoonotic or vector-borne diseases. Protection of public health also includes responsibilities stipulated in Opinion 8.3, "Physicians' Responsibilities in Disaster Response and Preparedness."[20] This opinion states that physicians have a professional obligation to provide urgent medical care in disasters, which include environmental and natural disasters.

Additionally, acknowledging ecological influences on health helps physicians understand and address health care disparities, such as those mentioned in Opinion 8.5, "Disparities in Health Care."[21] Environmental inequities parallel the health inequities experienced by vulnerable populations, which were clearly evidenced during the COVID-19 pandemic when essential workers who labored in crowded conditions were more likely not only to become infected with the virus and spread its to their communities,[22,23] but also to face moral injury due to inadequate workplace precautionary measures for disease prevention.[24] Collaborative, interdisciplinary clinical teams that aim to "expand access to care for populations of patients," as stated by Opinion 10.8, "Collaborative Care," are critical for ensuring the health and well-being of individuals and communities.[25]

Although there is still a significant need to continue exploring ecological influences on human health, the AMA *Code* provides helpful guidance on minimizing disease risk and transmission, in addition to encouraging collaborative and preventive care that can be applied alongside One Health and ecological frameworks.

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MEDICINE AND SOCIETY: PEER-REVIEWED ARTICLE

Why Climate Literacy Is Health Literacy

Larry R. Churchill, PhD, Gail E. Henderson, PhD, and Nancy M.P. King, JD

Abstract
Health problems of global warming are daunting in severity and magnitude and will only get worse. Yet literacy about these problems is poor and plans to alleviate them are too early in development to be responsive to current levels of global threat and individual need. Social and ecological determinants of health and illness are exacerbated by excessive heat and flooding; lack of food, safe water, and secure shelter; and loss of arable land for farming. This article considers the nature and scope of ethicists' roles in awakening clinicians and the public to this crisis and offers 4 recommendations to reduce morbidity and mortality from climate change.

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Health Literacy and Climate Literacy

The concept of health literacy has long been of concern to bioethics, which has focused on 2 considerations. First, bioethicists have helped prepare educational materials, develop clinicians' communication skills, and empower patients to ask questions, all to enable individuals to understand basic and personally relevant health information. Second, bioethicists have emphasized that "low" health literacy is not a stigmatized individual failing but rather a failure of public education and health care institutions. The definition of health literacy was revised in Healthy People 2030 to emphasize that individuals should be able not only to understand but also to use health-related information for their benefit, and, importantly, to emphasize organizations' role by defining organizational health literacy as "the degree to which organizations equitably enable individuals to find, understand, and use information and services to inform health-related decisions and actions for themselves and others."[1] This expanded definition places much-needed emphasis on the key justice component of health literacy: organizations' duty to "equitably enable" the health literacy of individuals.

Climate literacy expands this organizational duty and its justice implications because it requires not only educating populations about complex and politically contested data but also enabling effective use of those data. This latter requirement in turn entails changing not only individual behavior but also the practices of the very organizations that have contributed to climate change and health disparities in the United States and around the world. Bioethics and the medical establishment have a difficult and critically important task ahead: to help everyone fulfill their duty to understand and act upon information about climate change and its adverse and disparate health effects.[2]

Health Problems of Global Warming

The effects of climate change are profound, overwhelming, and increasingly severe. Melting polar ice; shrinking permafrost regions; rising and warming oceans; hotter average temperatures; increasingly frequent and severe forest fires, hurricanes, typhoons, and similar storms; and unprecedented flooding are part of what we are already experiencing and what we can expect to worsen.

The health consequences of these environmental changes are almost unimaginable. Massive numbers of deaths, especially among the world's poorest populations, will occur because of unrelenting heat, uninhabitable land, food and water shortages, and the breakdown of economies and national governments. Already a quarter of the earth's population lacks safe drinking water, with the result that nearly 2 billion people currently struggle to meet their daily needs for clean water.[3] By 2030, increased salination of irrigated farmland, evaporation caused by increased heat, and frequent flooding of coastal areas will mean that an additional 1 billion people will be without a safe source of potable water.[4] Moreover, climate change affects the spread, intensity, and seasonality of infectious diseases like malaria and cholera.[5,6] In general, climate change will produce a substantial increase in transmission of disease worldwide.[4] Heat emergencies, mental health disorders, and broader health problems like declining food safety and its consequences add to the growing damage of climate change.[7]

How fast is climate change happening? It is still unknown whether temperatures will rise at a predictably steady pace with the rise of greenhouse gas emissions or whether—the more likely scenario—there is a tipping point, caused by self-reinforcing feedback loops, beyond which devastating changes cascade and accelerate.[8,9] Yet, despite increasingly clear warnings, climate literacy is still in its infancy. As Al Gore emphasized, anthropogenic global warming is an "inconvenient truth," since the burning of fossil fuels is integral to the lifestyle of resource-rich industrial nations.[10] A high-carbon lifestyle is reflected in what we eat, where and how we live, what we wear, how often we fly, how far we drive, and what we consume more generally.

Health Literacy and Social Causes

To say that the medical and health care systems, especially those of advanced democracies, are ill-equipped to respond effectively to the health crises induced by global warming is a gross understatement. Health care itself has a very large carbon footprint.[11] Medical and health systems have focused almost exclusively on rescue medicine and very little on public health, which has resulted in widespread failure to address the key social determinants of health. *Social determinants* refer to education, employment status, stress, nutrition, and housing, as well as other structural factors and cultural norms—all understood now as powerful "fundamental causes" of health disparities, accounting for a substantial proportion of health outcomes.[2,12,13] People who live in poor neighborhoods with few educational opportunities, inadequate access to food, inferior housing, and low-paying jobs live shorter lives with greater morbidity.[14] These profound disparities of health and well-being are compounded when their bodies are Black or brown and they are also subjected to explicit and implicit racism.[15] Research demonstrating the social determinants of poor health has been conducted for decades,[16] yet we continue to support and lionize a medico-centric system of health care that addresses only the small proportion of illnesses in which modern medicine specializes.

What does all this mean for our ability to respond to health crises of global warming? It is imperative to acknowledge that the great preponderance of health deficits arising from global warming present as "social determinants." Fewer communities will be safe from flooding; adequate food and clean water will become harder to acquire; and access to health care professionals will be more difficult as clinics and hospitals struggle to treat more patients with increased morbidity. The fractured national response to the COVID-19 pandemic prefigures what is likely to occur with global warming without major shifts in priority setting. Excess deaths from COVID-19 in Hispanic and Black communities in the United States have been demonstrated repeatedly.[17,18] Whether we can avoid simply repeating this pattern in the era of global warming we are entering is a question of justice that has largely been neglected in bioethics.

Health Justice

For most of its 50 years as a field, bioethics has been handmaiden to clinical medicine and medical research, captured by the emphasis on curing rather than preventing disease. The reasons for this orientation are multiple. Large academic medical centers are where the jobs are, and cultural fascination with rescuing individuals by medical means has made "repair shop" medicine the preoccupation of both clinical medicine and bioethics.[19] In this paradigm, distributive justice issues—who will receive the scarce kidney, the vaccine in short supply, or the last intensive care unit (ICU) bed—dominate the literature. Similarly, distributive justice issues dominate bioethical analyses of the COVID-19 pandemic, as doctors and hospitals have struggled to fairly allocate admissions, ICU beds, respirators, nursing care, and—more recently—vaccines. Largely neglected have been the social forces that cause people from poor and minoritized communities to need greater access to these services and to die with greater frequency.

More attention to social determinants of health can be seen in the broader scholarly and policy environment of which bioethics is a part. Medical publications now routinely feature articles on the social determinants of health and disease[18,19]; institutions regularly pay attention to diversity, equity, and inclusion, as well as race and racism[20,21]; and the National Institutes of Health is fostering initiatives that explicitly devote attention to inclusion of neglected populations.[22,23] Bioethicists are increasingly aware of social determinants and recognize that the great injustices of society play themselves out in significant disparities in health status, health care access, and health outcomes.[24,25,26,27] Yet much more attention is needed if bioethics is to play any significant role in helping to meet the health challenges of global warming.

The following broad recommendations ask bioethics scholars to undertake professional and public education and advocacy to foster understanding and use of information about climate change and health disparities. This work will require partnership with clinicians, public health officials, policy makers, social epidemiologists, and others who make essential contributions to reducing health disparities by addressing their fundamental causes. The recommendations are directed not only to bioethicists, but also to health care professionals and organizations, health professional students, and the general public. Countering global warming and its health effects will take all of our efforts.

Recommendations

1. Bioethicists, medical students, and clinicians should help medical institutions reduce their degradation of the environment, as large health centers—where many bioethicists work—have huge carbon footprints, thus damaging public health even as they provide treatment.[2]

2. Recognizing the many social causes of ill health means that "all policy is health policy,"[28] including housing, transportation, food, water, energy, urban development, and education, and, accordingly, that all stakeholders have advocacy roles. Just how powerfully all these policies affect health will become increasingly clear as global warming accelerates. The environmental consciousness promoted by the Biden Administration for all sectors of government[29] must also be taken up by local and state governments and by industry leaders.

3. Effectively meeting the justice challenges of health in the era of global warming entails recognizing and working to eliminate the pervasive health effects of racism. The choice before us is a neoliberal Anthropocene era, in which existing inequities are simply allowed to play themselves out, or a more democratic Anthropocene era in which benefits and burdens are shared and people recognize their radical interdependence and the need for solidarity.[30] Any possible human survival and flourishing depends on taking the latter path.

4. It is imperative for bioethicists to help foster greater climate literacy on the part of the public. Without it, the millions that the oil, gas, and coal industries spend on congressional lobbying—over $124 million in 2022[31]—will delay any national response until it is too late. Pressure on public officials by a more climate-savvy public is a sine qua non for effective change, and perhaps for our very survival.

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MEDICINE AND SOCIETY: PEER-REVIEWED ARTICLE

How Should a One Health Perspective Promote Cross-Disciplinary Research About Bat-Associated Viruses in Uganda?

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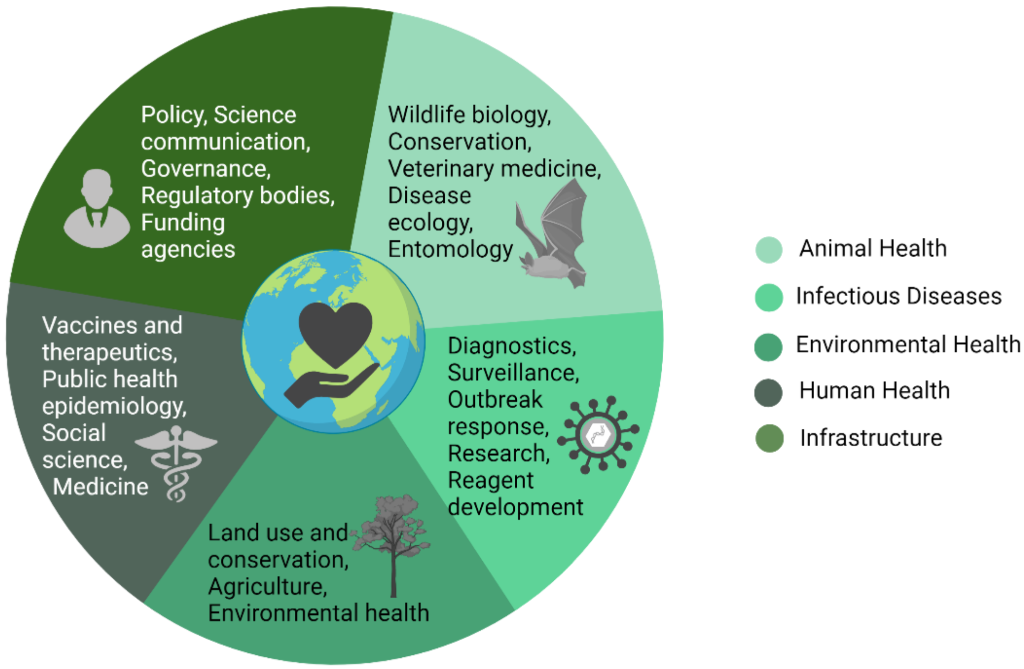
Abstract
Bats are diverse mammals that are globally distributed and ecologically critical, yet some bat species are associated with disease agents that have severe consequences for human health. Disease outbreak responses require interdisciplinary knowledge of bat-associated pathogens and microbial transmission patterns. Health promotion requires close, collaborative attention to the needs, vulnerabilities, and interests of diverse stakeholders, including the public and professionals in public health, conservation, ecology, social science, communication, and policy. This article describes a successful One Health engagement among such stakeholders and partners looking to motivate both bat-human ecology preservation and viral disease management in Uganda.

Convergence and Disease

Zoonotic infectious disease emergence is a complex process that necessitates understanding the vertebrate reservoir ecology; circulation, shedding, and maintenance of the infectious agent in its natural reservoir host; reservoir-human or environmental contacts that may lead to human exposure; and intrahost immunological barriers that may protect against infection.[1] This convergence of human, animal, and environmental health in the context of infectious disease dynamics underpins One Health, which the Centers for Disease Control and Prevention defines as "a collaborative, multisectoral, and transdisciplinary approach—working at the local, regional, national, and global levels—with the goal of achieving optimal health outcomes [by] recognizing the interconnection between people, animals, plants, and their shared environment."[2] The One Health framework has become a cornerstone of global infectious disease investigations,[3,4,5,6] building on a growing appreciation for how changing landscapes, human encroachment onto pristine habitats, and interconnected global travel facilitate the spread of infectious agents.

One Health provides an interdisciplinary framework for understanding the nature of initial spillover events and mitigating subsequent pathogen transmission. Significant contributions from animal health, infectious disease, environmental health, human health, and governmental sectors, as well as interdisciplinary engagement among these groups, are essential to a comprehensive mission with One Health at the center (see Figure). From the perspective of studying the viral ecology of bats in Uganda, we posit that interdisciplinary approaches within this One Health framework are essential to the successful investigation and response to zoonotic infectious disease events, and we present key opportunities for effective cross-disciplinary engagement in this context.

Figure. Conceptual Interdisciplinary Framework for One Health Investigations on Zoonotic Emerging Infectious Diseases



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Animal Health

By occupying a diverse range of ecological niches, bats provide numerous and critical ecological services, such as pest insect consumption, seed dispersal, and pollination.[7] Yet some bat species are associated with highly consequential human pathogenic viruses, including lyssaviruses,[8,9] coronaviruses,[10,11] paramyxoviruses,[12,13] and filoviruses.[14] The fear of bats and the negative association of emerging diseases with bats threaten the wildlife conservation mission and raise issues about animal welfare, despite wildlife conservation being integral to One Health.[15] In Uganda, for example, miners' fear of Marburg virus triggered a mass culling of Egyptian rousette bats in a mine in 2008.[16] However, by 2012, bats had recolonized the mine, and Marburg infection rates were higher than during the 2007 to 2008 outbreak.[16] Similarly, the government of Mauritius ordered multiple mass cullings of the endangered Mauritius fruit bat (*Pteropus niger*), reportedly due to fruit crop damage.[17]

While this discordance between conservation goals and infectious disease control has created tension within the bat research community,[18] a One Health perspective recognizes that the protection of bats and their habitats from anthropogenic disturbance and the protection of humans from zoonotic disease function together as one interconnected system.[15] For example, understanding how viruses circulate in bat populations provides insight into both drivers of pathogen shedding as it relates to human health risk and potential risks to bat health from human encroachment and bats' interactions with domestic animals. Thus, wildlife professionals' insights on bat ecology are essential to protecting bats and mitigating risks to people and livestock. In particular, wildlife veterinarians applying a One Health framework are in a unique position to act as liaisons between human medical professionals and wildlife biologists, whose interests have rarely overlapped previously.[19]

In the ecological system the authors study in Uganda, peri-domestic animals can have contact with cave-dwelling bats and with bat waste, including feces, urine, and partially eaten fruits. Cattle, goats, dogs, and various wildlife species enter caves for salt or other micronutrients, for protection, and possibly to hunt or scavenge bats. These species may then have contact with other domestic animals or people, directly or indirectly, creating a potential chain of contact by which infectious agents could be transmitted from one species to another. Moreover, that bat roost sites often have no deliberate protection and increasingly are encroached upon by human settlements raises concerns about increased human-bat contact.[20] The senior author (R.C.K.) and a colleague have argued that understanding and mitigating potentially complex spillover events from bats can be facilitated through a One Health emphasis on open communication and interdisciplinary collaboration among bat ecologists and infectious disease researchers.[18] Namely, identifying how existing research programs can be leveraged to further common agendas, building new research domains that address questions fundamental to both disciplines (eg, bat health), and strengthening relationships to facilitate knowledge transfer can all break down barriers to interdisciplinary collaboration.[18] International organizations such as the Global Union of Bat Diversity Networks (GBatNet)[21] and the International Union for Conservation of Nature Bat Specialist Group[22] have already made great strides in facilitating interdisciplinary, action-oriented engagements between bat researchers focused on conservation and on infectious diseases. For example, GBatNet has assembled a number of interdisciplinary working groups to tackle cross-cutting One Health issues, including bat health and stress, science communication, and the impact of climate change.[21]

Human Health
Medical professionals are expert at early recognition of atypical disease presentations as well as characteristic signs and symptoms, case definition development, treating patients, evaluating vaccines and therapeutics, and communicating with public health agencies and regulatory stakeholder groups, but they are only one part of a One Health approach to infectious disease control. Before One Health, One Medicine recognized commonalities between human and veterinary medicine's shared epidemiological approaches to combatting human and veterinary diseases and called for collaboration to address zoonotic disease.[23] The need for a collaborative approach to achieve this goal is apparent in Uganda, where human-bat-cave interactions have resulted in disease outbreaks,[13,14,16] but rural disease reporting capabilities are limited. Despite having a village health team (VHT) network for community disease surveillance, volunteers are challenged by inadequate access to transportation for surveillance data collection; lack of data analysis and storage capacity; no coordination among environmental, wildlife, or livestock surveillance; and inability to use mobile phones for data reporting.[24] Experts' engagement with communities is essential for early recognition and response to emerging infectious disease events. While Uganda has formalized a National One Health Platform for advising government agencies and coordinating their responses to zoonotic diseases, this endeavor lacks financial backing and actual intersectoral coordination.[25]

Such cross-agency coordination of One Health surveillance activities that include VHTs would be game changing for the transmittal of disease information from communities to district and national task forces responsible for rapid epidemic and emergency response.[24,25] Moreover, interdisciplinary collaboration is key to understanding and mitigating spillover events, as collaboration among physicians, veterinarians, and wildlife biologists enables clinical disease symptoms to be traced to unusual bat exposure events.[13] Similarly, social scientists and anthropologists can work with disease ecologists and wildlife researchers to determine human behaviors and interactions with reservoir hosts or vectors that predispose people to zoonoses and may facilitate the emergence of zoonotic spillover events,[26] thereby enabling the development of targeted intervention strategies (eg, educational campaigns in schools and training workshops for district officials).

Environmental Health

With less than 3% of the earth's terrestrial surface qualifying as "intact,"[27] there is increasing need for cross-disciplinary collaborations to ensure healthy environments for all species. Environmental changes associated with urbanization, human population growth, increasing demand for animal protein, intensive farming systems, unsustainable natural resource consumption, biodiversity loss, and habitat fragmentation all contribute to the emergence and spillover of infectious diseases primarily through enhanced human-wildlife interactions.[28] How can we ensure that vulnerable communities experience food and financial security without destabilizing habitats in a way that creates new risk for zoonotic disease emergence? This intersection of social and environmental sciences raises questions about how best to support the health and prosperity of rural impoverished communities living in or adjacent to fragile, protected ecosystems.

In Uganda as elsewhere, the proportion of land area under some form of protection is small for the size of the country and is shrinking due to human activity,[29] which has consequences for the environment and for human and animal health. Natural land cover is important for maintaining healthy communities and populations of bats; such habitats preserve ecosystem function and limit human-bat interaction. Bats in protected and unprotected areas, however, face increased anthropogenic disturbance, which threatens the natural buffers of our ecosystems, causing a disruption in the flow of ecosystem services. Moreover, the encroachment of human settlements into areas where bats may be foraging for fruits or insects increases the potential for human-bat contact and raises concerns about spillover risk.[20] The increased environmental stress can also impair wildlife immunity, causing increased shedding of pathogens to the environment, where humans and animals may be exposed.[30] Thus, habitat conservation should be the aim of multidisciplinary efforts to protect bat populations and to limit bat interactions with people and thereby minimize spillover risk of bat-borne pathogens. As provided for under Section 35(1)(f) of the Uganda Wildlife Act of 2019,[31] local communities living along the Mt Elgon National Park border are permitted to enter the park weekly to sustainably harvest resources such as medicinal plants, mushrooms, grass for thatching houses, fish, and fuel wood as one of the solutions for promoting environmental and public health protection.

Infrastructure and Infectious Diseases

It is imperative to have highly trained infectious disease scientists and a laboratory infrastructure to support safe zoonotic disease investigations, biosecurity during research, and emergency response efforts. In Uganda, the Uganda Virus Research

Institute (UVRI), founded in 1936—one of the premiere infectious disease institutions in Africa—subserves these functions. At UVRI, more than 124 virus strains of 14 new viruses have been isolated, including West Nile virus and bat-associated viruses.[32] The UVRI conducts research, surveillance, and diagnostic activities and serves as a World Health Organization reference and testing laboratory.[33]

Recently, an international collaboration led to the development of the Laboratory Response Checklist for Infectious Disease Outbreaks.[34] This checklist specifies that outbreak investigative teams—comprising epidemiologists, laboratory diagnosticians, wildlife professionals, risk analysts, and infectious disease specialists—should provide extensive interagency and institutional coordination among stakeholder groups to implement disease surveillance and effective response measures. Such coordination ensures that viable samples are safely collected from humans, animals, and the environment to monitor causative pathogens. The outbreak data collected should be analyzed to discover behavioral dynamics, clustering patterns, and disease hotspots, and molecular and phylogenetic studies should be carried out to draw evolutionary inferences about disease agents, unveil complex zoonotic cycles, assess vector competence, and discover genetic variations of pathogens. At the same time, research laboratories should develop diagnostic assays and protocols to roll out to public laboratories for surveillance purposes. However, while diagnostic tests exist for most pathogens, availability is often limited, especially in developing countries, and some kits are not in formats that can be deployed at the community level. Importantly, an effective disease outbreak communication strategy necessitates rapid and accurate data sharing among policy makers and collaborating partners to respond to public concerns and guide decisions on allocation of available resources.[34]

An infrastructure that supports a One Health mission for zoonotic disease investigations must encompass these diverse and complex interdisciplinary activities. In addition, because typical challenges faced in implementing a One Health platform have included effective coordination across stakeholder groups and the sustainability of government financial support,[25] there must be mechanisms to promote interagency cooperation in the event of an outbreak (ie, ministries of health, agriculture, environment, and wildlife) and funding to acquire reagents and laboratory supplies for diagnostics and surveillance, as well as to meet other response needs. There must also be collaborations among manufacturing experts, biotechnologists, and regulatory agencies to enable production of safe and effective vaccines and therapeutics at a reasonable cost. Bringing vaccines and therapeutics to the public in turn will require vaccinology experts to partner with sociologists, industry, and governmental agencies to ensure compliance with vaccination programs by the target community.[26]

A Future of One Health

Despite lingering challenges, Uganda has experienced success in applying the One Health framework. The nongovernmental organization Conservation Through Public Health has successfully integrated pathogen surveillance into conservation and public health services in multiple districts throughout Uganda to monitor zoonotic disease transmissions among wildlife, humans, and livestock.[35] Moreover, academic institutions have the capacity to train students and conduct interdisciplinary research, which not only builds a sustainable workforce but also enables collection of real-time data on which evidence-based policies can be based. For example, Makerere University has implemented a One Health Institute, a didactic training curriculum, and a Student One Health Innovation club to develop One Health competencies among students entering the workforce.[36] Programs like that at Makerere University are instrumental for training collaborative-minded students who are bound for national and global health positions and committed to promoting a One Health approach. The viral ecology of bats in Uganda offers another unique One Health opportunity, given that Uganda has an infrastructure for infectious disease response and a history of viral hemorrhagic fever outbreaks, including of strains associated with bats. In our experience, interdisciplinary partnerships that span academic, private, and government entities bring together the necessary interdisciplinary expertise to carry out ecological and infectious disease research on bats that supports actionable policy and is built on the recognition that public health protection is not limited to human-focused efforts but is intimately connected with environmental health and conservation initiatives. Prevention of the next pandemic associated with a zoonotic disease agent may depend upon our taking a collaborative, One Health approach to public health protection.

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MEDICINE AND SOCIETY: PEER-REVIEWED ARTICLE

Can One Health Policy Help Us Expand an Ethics of Interconnection and Interdependence?

Karen M. Meagher, PhD

Abstract

One Health—a holistic approach to health that brings the moral status of animals and environments into consideration—is understood as a "professional imperative," a value-laden obligation that flows from the scope and objectives of professional roles. In this article, antimicrobial resistance provides a case study to demonstrate the fruitfulness of public health and bioethics collaborations by applying One Health key concepts of interconnection and interdependence. Moving toward an ethics of One Health requires a more nuanced analysis of ecological relationships, including humans' connections to other species as hosts, vectors, domestic companions, meat-eaters' food, and farmers' livelihood.

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Introduction

Infectious diseases are a paradigmatic example of the interconnectedness of health behaviors and health outcomes. If you are infected with a virus and do not mask, I am exposed to it. Whether you like it or not, my cough can determine whether you spend the weekend in bed. A One Health approach to health extends relevant interconnections from humans to animals and our environments. One Health is defined as "a collaborative, multisectoral, and transdisciplinary approach—working at the local, regional, national, and global levels—with the goal of achieving optimal health outcomes recognizing the interconnection between people, animals, plants, and their shared environment."[1] It is a useful approach, especially for health problems involving interspecies connections. Antimicrobial resistance in bacterial, viral, and fungal pathogens is a multifactorial challenge that is especially well captured by a One Health model.[2] Resistance can be intrinsic, as when cell wall structures create barriers that block antimicrobials from entering the cell. Resistance can also be acquired, since with each exposure to an antimicrobial treatment, microbes with the genetic capacity to withstand (resist) the medicine are more likely to survive. And, unlike human genes that are only shared from generation to generation, bacteria can share genes horizontally, or among members of a colony. These multiple modes of gene transfer enable bacteria to develop the capacity to resist antibiotics very quickly.[3]

Antimicrobial treatments and resistance are dual public health and moral dilemmas. We need to reduce suffering from infections, but the more we use antimicrobials against pathogens, the more we create the conditions for resistant strains to become dominant, which increases suffering from infections in the future. A One Health model helps us plan and act with greater coordination. It does so by recognizing how microbes and antimicrobial-resistant pathogens can be transmitted across species, thereby directing policy attention to antimicrobial use across human, veterinary, and agricultural sectors simultaneously.[4] Applied to problems of antimicrobial resistance, a One Health approach highlights how environmental, animal, and human uses of antimicrobials must be coordinated among many stakeholders and involve complex considerations. Yet the ethical and social aspects of antimicrobial resistance are understudied.[5] In this article, antimicrobial resistance provides a case study to demonstrate the fruitfulness of public health and bioethics collaborations by analyzing One Health key concepts of interconnection and interdependence.

Other-Regarding Behavior

John Stuart Mill's harm principle provides a broad justification for public health policy by distinguishing between self-regarding and other-regarding behavior: "As soon as any part of a person's conduct affects prejudicially the interests of others, society has jurisdiction over it, and the question whether the general welfare will or will not be promoted by interfering with it, becomes open to discussion."[6] For Mill, other-regarding behavior is a necessary criterion for justifying state restriction of individual liberty in cases of harm prevention. A One Health approach extends Mill's harm principle beyond nation states and beyond human-only relationships by explicating the far-reaching consequences of human behaviors across borders and species. For instance, a One Health approach is responsive to increasing evidence of the harms of land-use policies that value maximum yields and intensive practices—factors contributing to higher antimicrobial use[7,8,9]—with the United States being among the leading contributors to antimicrobial use in agriculture.[10]

A One Health approach to complex causes is also consonant with a variety of environmental ethics traditions. For example, Peter Singer's championing of animal rights extends the consequentialist tradition by deeply examining the negative ramifications of human meat consumption for animal suffering and environmental sustainability.[11] Moreover, Van Rensselaer Potter's vision of bioethics embraces multidisciplinary research and action, endeavors that "would attempt to generate wisdom, the knowledge of how to use knowledge for social good."[12] Potter's vision has recently been reinvigorated, partly in response to global health challenges like antimicrobial resistance and climate change.[13] Like climate change, antimicrobial resistance heightens the importance of time in our moral and political deliberations. The rise of pathogens that can resist treatment highlights intergenerational justice: what we (fail to) do now to conserve antimicrobial effectiveness determines the infectious disease burden borne by those in the future.[14]

Interconnectedness and Interrelatedness

As with other-regarding behavior, One Health often draws a straight line between interconnectedness and the moral obligations that arise from it. For example, in the Centers for Disease Control and Prevention One Health social media graphics, interconnectedness immediately translates to a promissory rhetoric of collective health action and protection: "One Health is the idea that the health of people is connected to the health of animals and our shared environment…. When we protect **one**, we help protect **all**."[15] Implicit appeals like these are a starting point for developing a more explicit One Health ethics.

However, as Jonathan Beever and Nicolae Morar note, interconnectedness is conceptually proximal to, but distinct from, interdependence, although the two are often conflated.[16] Interconnectedness may entail simple causal dependence, such that one factor determines the other: use of antibiotics for infections leads to patient satisfaction when symptoms resolve. In ascertaining causation, researchers typically seek to control one factor—such as antibiotic prescribing—to determine its influence on a dependent variable, such as patient demand. In antimicrobial resistance, the causal interconnections involved are so complex they have even been dubbed "super-wicked."[17] For conceptual clarity, it is worth distinguishing 3 forms of interconnectedness when thinking about antimicrobial resistance. I will refer to these as *epistemic, practical,* and *collective* interconnectedness.

- *Epistemic.* Epistemic interconnectedness refers to our understanding of the causal factors driving the rise of antimicrobial resistance. A One Health approach delineates how sources of human disease and ecosystem collapse are related to one another; a better understanding of these causal relationships can help us identify new forms of intervention to mitigate the development of resistance and to improve infectious disease outcomes.
- *Practical.* Practical interconnectedness reflects the more workaday reality of cross-sectoral and international policy making, which demands tremendous coordination, political negotiation, and logistical planning to have real impact.
- *Collective.* Collective interconnectedness refers to population health. The preventability and absence of infections—especially resistant infections—constitutes a state of affairs made possible by effective antimicrobials.[18] Such benefits are held by an entire community, including the currently uninfected. In contrast, widespread antimicrobial resistance is a collective harm, affecting all those who live in or near communities with difficult-to-treat strains of infection.

In contrast to interconnectedness, interdependence captures the normative aspect of forms of connection in which individual or group benefit turns on the behavior of another party.[16] There are many forms of interdependence, from deep need to receive and give (such as with an infant and parent) to transactional reliance (including contracts or market exchanges). Interdependence can be among our most valued connections, such as when love generates abiding and multidirectional sharing of vulnerability and advantage (mutuality). But interdependence can also be negative, such as in relationships of oppression, wherein those in power rely on systems of subjugation to extract goods and labor from others and in which the well-being of those who are subjugated rests on the restraint and mollification of those in power.

Confusion between interconnection and interdependence leads to a wide range of views about the role of ethics in a One Health approach. Some contend that One Health interdependence is meant to be a primarily descriptive term, carrying little or no normative weight.[18] In contrast, Henrik Lerner and Charlotte Berg have argued that a One Health approach inevitably bears normative implications—first, because it involves delineating which disciplines are included in its collaborative vision and, second, because the approach requires defending a distinctive definition of health for policy makers.[19] Splitting the difference, interconnection and interdependence strike me as highly related features of infectious diseases that challenge the fact-value distinction. They may be conceptually distinct, but they are practically entangled. That my health is causally connected to yours inevitably invites questions about how we take our shared or opposing interests into account.

One Health Ethics

A One Health approach needs a corollary account of how obligations flow from values as well as causal relationships. This approach is implicit in the understanding of One Health as a "professional imperative."[20] A professional imperative refers to a value-laden obligation that flows from the scope and objectives of professional roles. We need not start from scratch in seeking such an account. Because Mill was primarily concerned with delimiting state intervention in private life, a Millian ethos might start by delineating principles for imposing liberty-restricting measures. For example, although the public health harm of antimicrobial-resistant pathogens might be considered a justification for public monitoring of the quantity of antimicrobial prescriptions written by each clinician, challenges to clinicians' "right" to prescribe have sometimes been framed as an infringement on the clinical autonomy of practitioners.[21] However, public health also concerns ascription of responsibility based on consequences that follow from acts of omission as well as acts of commission. Within One Health, the imperative is to recognize that interdependence can be good—involving mutual benefit—and not merely an infringement of individual autonomy. As a result, bioethics and One Health collaborations might also consider the rationale for formation of policy grounded in intergenerational harm prevention, given the morbidity and mortality that will befall future populations if antimicrobial resistance is not effectively mitigated.

We also need ethical and political analyses of situations in which individual and collective freedoms or rights conflict in the context of antimicrobial resistance. Such analyses are needed as a corrective to Western European cultural biases, which can overly emphasize individualism, and could encompass a range of other-regarding relationships—ranging from domination, exploitation, and complicity to dependence, trust, and care.[21,22,23,24,25,26] In the end, a One Health ethics will need a holistic ethos of individual and collective action. As Onora O'Neill has articulated, bioethical conceptualizations of autonomy sometimes render other forms of reliance—such as trust—undesirable.[27] In other words, if we depict the best relationship to health as independence from others so we can each choose, are we doing unintentional damage by suggesting that all forms of dependence are undesirable? A One Health ethics would advance efforts to enact health policies that recognize the connections, conceptually and practically, between individual and community, freedom and public benefit.

Conceptual clarity and practical action are especially relevant to a One Health approach, wherein interdependence plays a central role. As with interconnection, accounts of interdependence in public health ethics are widely varied (See Table).

Table. Public Health Ethics Conceptual Accounts of Interdependence

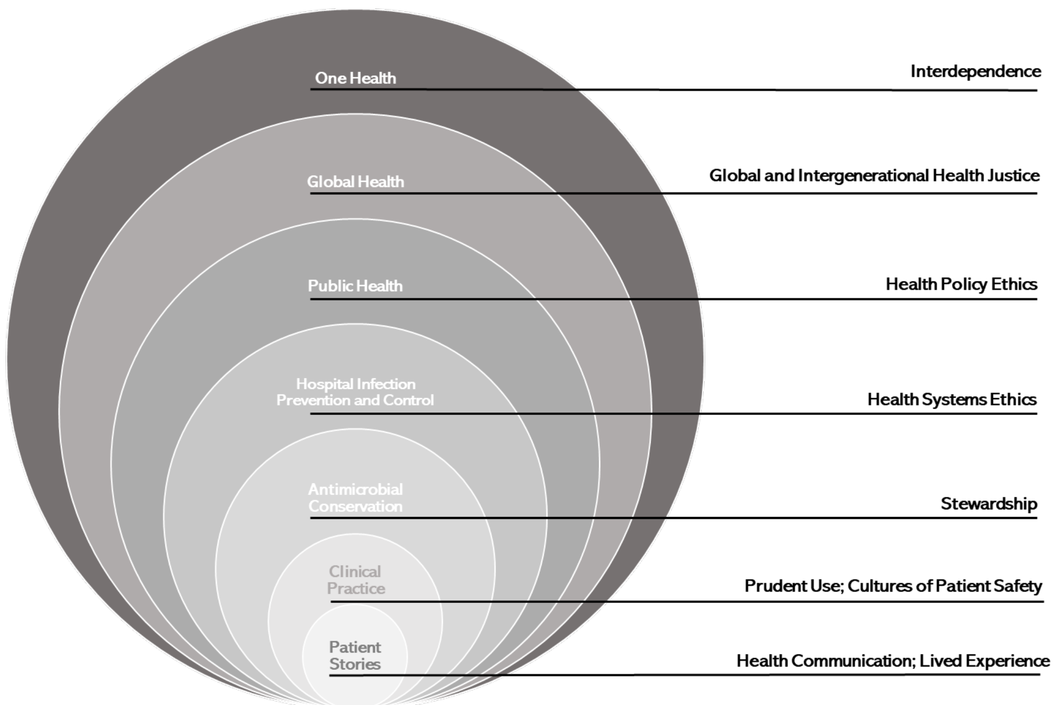
Source	Conceptual account
American Public Health Association 2019[28]	*Interdependence and solidarity.* The health of every individual is linked to the health of every other individual within the human community, to other living creatures, and to the integrity and functioning of environmental ecosystems. Public health practitioners and organizations have an ethical obligation to foster positive—and mitigate negative—relationships among individuals, societies, and environments in ways that protect and promote the flourishing of humans, communities, nonhuman animals, and the ecologies in which they live.
Swain 2008[29]	*Interdependence.* Interdependence involves achieving community health in a way that respects individual rights, while recognizing that the health of some often depends on the health of others. The principle of interdependence also leads public health practitioners to consider the social and economic consequences—in addition to the health consequences—of their emergency planning and response efforts.
Nuffield Council on Bioethics 2007[30]	*Fraternity, solidarity, or community.* "What is required is a value that expresses the way that we each benefit simply from being members of a society in which the health needs of others are addressed. There is no settled term for this value: some speak of 'fraternity,' others of 'solidarity.' We prefer the term 'community,' which is the value of belonging to a society in which each person's welfare, and that of the whole community, matters to everyone. This value is central in the justification of both the goal of reducing health inequalities … and the limitation on individual consent when it obstructs important general benefits. Public health often depends on universal programmes which need to be endorsed collectively if they are to be successfully implemented."
Nieuwland 2019[18]	*Interdependence.* Interdependence perhaps requires us to go beyond the epidermal layers that separate animals from their "environment": "The separation between internal physiological and external ecological processes affecting one's health reflects an individualization unwarranted given the way the health of humans and animals fundamentally depends on both of these conditions."

Explicating an ethics of interdependence is a key task for advancing ethics and One Health policy. Collective interconnection, such as the shared impacts of widespread antimicrobial resistance, raises questions about interdependence—how we distribute or share responsibility when we rely on each other to coordinate action because of our shared fate. Take the example of a farmer on the East Coast whose use of antimicrobials to increase the growth rate of his turkey flock possibly (highly contingently) increases the chance of a 21-year-old in the Southwest dying from an antimicrobial-resistant infection. The contingencies make it difficult to attribute antimicrobial resistance to a single or significant casual factor. In parallel, any related responsibilities are also challenging to justify and assign. Analysis of collective responsibility for antimicrobial resistance on the population or systems level would provide stronger causal evidence—and perhaps stronger normative grounds—for policy change. It is known that the greater the demand for meat, the greater the use of antimicrobials for growth promotion, and the higher the chances of generating antimicrobial resistance in human populations.[31] A One Health ethics cries out for greater clarity on how different forms of connection and dependence might generate distinct responsibilities. For example, are national obligations to mitigate antimicrobial resistance distinct? That is, what do affluent nations owe low- and middle-income countries when the affluent have more resources to dedicate to mitigating the development of antimicrobial resistance? As an ethics of interdependence is developed, its relevance for population health challenges other than antimicrobial resistance—such as chronic diseases that also require policy coordination—can also be examined.[32]

Antimicrobial Resistance

A One Health approach sets the broadest backdrop for exploring social and ethical questions that arise in relation to antimicrobial-resistant infections. A shared appreciation for pragmatic, interprofessional problem solving in bioethics and One Health provides a shared starting point for future collaborations. For social scientists, a research goal might be to critically analyze how antimicrobial resistance results from interdependence and how interdependent relationships are made possible or discouraged by social systems. For ethicists, analysis of interdependence often involves value-based assessments of whether such interdependencies are good or desirable, generate obligations, or violate rights of parties. Public health practitioners with environmental, agricultural, and health policy expertise also have key contributions to make in future collaborations. Beyond the One Health level of analysis, antimicrobial resistance calls for similar efforts to advance multidisciplinary team science. Other pertinent levels of analysis range from patient-clinician relationships to meso-level contexts much narrower than the One Health framing (see Figure).

Figure. Levels of Analysis for Advancing Research on Ethical and Social Aspects of Antimicrobial Resistance



The complexity of antimicrobial resistance lends itself to multiple framings.[33,34] Rather than viewing frames as competing approaches, multidisciplinary teams might employ different frames to focus on an element of antimicrobial resistance. A One Health backdrop serves as a reminder to avoid oversimplification by keeping interconnection and interdependence front and center as new solutions are envisioned, designed, and implemented.

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MEDICINE AND SOCIETY

How High Reliability Can Facilitate Clinical, Organizational, and Public Health Responses to Global Ecological Health Risks

Lloyd Duplechan

Abstract
High reliability organizations operate in complex, high-hazard domains for extended periods without serious accidents or catastrophic failures. High reliability can be described as a condition of persistent mindfulness within an organization, coupled with a relentless, assiduous prioritization of adverse event prevention. This article describes ethically and clinically relevant features of high reliability that health care organizations can draw on to anticipate, identify, and respond to global ecological health threats.

High Reliability and Global Health

In February 2023, the West African country of Equatorial Guinea declared an outbreak of Marburg virus disease, formerly known as Marburg hemorrhagic fever.[1] There had been at least 9 laboratory-confirmed cases, 7 of which resulted in death during this outbreak, according to the World Health Organization.[1] The pathogen likely spilled over from wild animals to humans. In 1967, the Marburg virus was identified when outbreaks of the disease in Marburg and Frankfurt, Germany, and in Belgrade, Serbia, were traced to African green monkeys imported from Uganda that were being used in laboratories.[2] Outbreaks of Marburg virus disease have typically resulted from prolonged exposure to mines or caves inhabited by *Rousettus* bat colonies.[3] As many species of bats are endangered,[4] disease prevention campaigns to protect people living close to bat-inhabited caves and tourist groups become complex undertakings. While there have been no reported Marburg virus disease diagnoses in the United States, the World Health Organization believes the disease has epidemic potential,[2] and the Centers for Disease Control and Prevention (CDC) seeks to "increase awareness of the risk of imported cases in the United States."[5]

These outbreaks of Marburg virus disease underscore that the world's ecosystems are fragile, delicately balanced, and complex systems, and, as such, rife with potential for collapse and health threats. The consequences of failure within these complex systems could be dire. Moreover, health threats such as viral spillover or spillback can be accelerated by climate change and exacerbated by undesirable socioeconomic conditions,[6] such as overcrowding. This article argues that health care organizations could benefit greatly from the adoption of systematic methods conducive to high reliability to effectively respond to global ecological health risks and, to this end, canvasses key principles and practical considerations pertaining to high reliability for health care and public health organizations.

High Reliability Organizations

The construct of *high reliability organization* (HRO) was originally applied to high-hazard industries, such as nuclear power and commercial aviation, to achieve minimal errors. Arguably, these are industries in which even a slight error can have catastrophic consequences.[7] In 1984, Yale sociologist Charles Perrow published a groundbreaking book, *Normal Accidents: Living with High-Risk Technologies*, which provides a detailed analysis of complex systems from a sociological perspective.[8] It was the first to propose a framework for characterizing complex technological systems, such as air traffic, marine traffic, chemical plants, dams, and especially nuclear power plants, by inherent risk.[5] Subsequently, a group of researchers at the University of California, Berkeley (Todd La Porte, Gene Rochlin, and Karlene Roberts) studied *Normal Accidents* and how organizations working with complex and hazardous systems operated error free.[9] While many of their findings related to structure, they also showed that culture and decision-making processes had the potential to challenge some of Perrow's original tenets, and the results of these studies helped give rise to what is recognized today as the concept of HRO.[9]

Health care organizations comprise complex, sophisticated, high-risk systems and technologies; significant and even potentially catastrophic consequences could ensue should failures occur. For this reason, health care and public health organizations would benefit greatly from the incorporation of HRO principles in their leadership, organizational structure, operations, and systems, as well as in their foundational culture.[10]

Basic HRO Principles

Reliability can be defined as the quality of being trustworthy or performing consistently well. To realize this quality, the HRO framework should be underpinned by 3 pillars: (1) leadership commitment, (2) a culture of safety, and (3) process improvement. In their book, *Managing the Unexpected: Resilient Performance in an Age of Uncertainty*, Karl Weick and Kathleen Sutcliffe defined 5 principles of HROs,[11] which the Agency for Healthcare Research and Quality later adopted for the health care setting.[12] These principles amplify and build on the 3 fundamental ideas mentioned above and furnish the basic structure of HROs.

Preoccupation with failure (and the anticipation and prevention thereof). Upholding this principle involves assiduously examining processes and conditions to ferret out "what could possibly go wrong" (taking Murphy's Law literally). An example of a familiar method for carefully and systematically reviewing a process and its associated risks to anticipate and mitigate the occurrence of failure is failure modes and effects analysis (FMEA)—also called failure modes, effects, and criticality analysis.[13] Originally developed by the US military in the 1940s, FMEA is a proactive, step-by-step process-analysis tool for identifying all possible failures in a design or process—or "failure modes"—and "effects analysis" refers to study of the consequences of those failures.[13]

Sensitivity to operations, or strong consideration of the purpose, integration, and complexity of relevant systems and processes. One example of the application of this principle is Harvard Business School's study of the 2003 Columbia space shuttle disaster.[14] This study included a poignant review of the culture of the National Aeronautics and Space Administration's space shuttle program and takeaway lessons, including organizational decision making, understanding how failures can evolve and be prevented, and how to manage crises effectively.[14]

Reluctance to simplify. Novelist Jack Kerouac once said, "One day I will find the right words, and they will be simple."[15] With all due respect to Kerouac's commitment to simplicity and other common principles like the "KISS" method (keep it simple, stupid) or Occam's Razor (the law of parsimony), I contend the opposite: a reluctance to simplify means accepting that operations are very complex and anticipating that the risk of failure is inherent in complicated and tightly coupled systems.

Commitment to resilience. Resilience can be defined as the capacity to recover quickly from difficulties. In the context of organizations, resilience—how well and how quickly an organization bounces back, adjusts, and recovers—can be developed by prioritizing contingency planning and training in response to possible, albeit unlikely, system failures or unforeseen difficulties.

Deference to expertise. This principle involves seeking out staff with the most pertinent knowledge and privileging their insights and perspectives over those of staff members with greater seniority or in a higher position in the organization. For example, administrators could ask environmental services or housekeeping staff for ideas about better management of waste streams that could potentially contribute to release of methane and carbon dioxide (CO_2) in landfills.[16]

HRO and a Culture of Safety

Layering concepts of patient safety onto a bedrock of high reliability is a natural progression for hospitals, especially since—ironically—hospitals can be quite unsafe.

In 1850, Hungarian physician Ignaz Semmelweis stood behind the lectern at the Vienna Medical Society's lecture hall and bravely presented a lifesaving epiphany that could be summed up in 3 little words: wash your hands![17] His colleagues and other medical professionals, however, were incredulous, mainly because they refused to accept the idea that they could be responsible for spreading infections.[17] In today's hospitals, according to the CDC, about 1 in 31 patients has at least 1 health care-associated infection on any given day.[18] When patients enter the facility's doors, it demonstrates their trust in the organization's covenant. This promise dates back to the Hippocratic Oath itself.[19]

It is imperative that patient safety culture be essentially hardwired and exist at all levels and in all aspects of the organization and that it embody shared values, attitudes, norms, beliefs, practices, policies, and behaviors about safety issues in daily practice.[20] Safety culture is what is often referred to as "speak up culture." A recent *LinkedIn* article defines speak up culture as a healthy, supportive environment in which people can speak up and speak out, where they can feel emboldened to point out both challenging areas and opportunities for new disruptions and innovations.[21] In the context of health care organizations, staff at all levels—regardless of seniority or clinical discipline—should feel safe enough and confident enough to raise their hand if something just doesn't feel right: "see something—say something."

Interweaving a culture of safety into the fabric of an organization requires an important, albeit uncomfortable, commitment to depart from the old way of doing things. Defending "how we've always done it" allows what author James O'Toole described as the "despotism of custom."[22] If the status quo remains unchecked and unchallenged, mediocrity can engulf an organization like kudzu. Leaders must be true paladins of safety and quality and not merely a group of prefects and school hall monitors.

High Reliability and Climate Change

It appears that man's neglect and lack of environmental stewardship has helped to elevate Shakespeare from poet to prophet. The earth's atmosphere is indeed rapidly becoming a "foul and pestilent congregation of vapours."[23] In 2020, the United States' first-ever trial in a constitutional climate lawsuit commenced in Helena, Montana. In the case (*Held v Montana*), 16 young plaintiffs, ranging from 2 to 18 years of age when the suit was filed, alleged that Montana state officials violated their constitutional right to a healthy environment by enacting pro-fossil fuel policies.[24] On August 14, 2023, a district court judge ruled in the plaintiffs' favor.[25] Needless to say, this ruling makes a powerful statement, analogous to the rock band Twisted Sister's anthem, "Oh we're not gonna take it; No, we ain't gonna take it … anymore."[26]

Climate change is no secret and definitely not a hyperbolic, contrived conspiracy myth: studies show that increased spates of extreme rainfall, flooding, blistering heat waves (paleoclimatologists reported that, by mid-year 2023, the earth had reached its highest average temperatures in recorded history[27]), and arid drought have occurred over the past 20 years, which are causing or contributing to wildfires, crop failure, global economic challenges, infrastructure damage, and even devastating health crises.[28] Recently, professor of geosciences at Pennsylvania State University, Richard Alley, poignantly stated that the current rise in global temperature "is not natural, but caused by us."[28] Scientific data confirm that these weather changes and damaging environmental conditions are attributable to burning petroleum-based fuels and other human activity, including improper management of solid wastes. Landfill gas, a natural byproduct of the decomposition of organic material, comprises mostly methane and CO_2.[16] According to a recent assessment by the Intergovernmental Panel on Climate Change, 1 ton of methane is equivalent to 28 to 36 tons of CO_2 over a 100-year period.[29]

Applying the principles of HRO as part of an organization's culture of safety and environmental stewardship can greatly assist in anticipating risks of harm. Examples of HRO in this context include designing and implementing sustainability processes and protocols and environmental management systems (eg, fashioned after ISO 14001, an international standard that provides a framework for an effective environmental management system[30]) and the use of technologies and procedures—from energy and carbon emissions reduction to compliant waste management practices—that are sustainable across the board and that reflect fervent stewardship. In this context, commitment to resiliency starts with proactive steps that can take the form of continuous hazard vulnerability analysis, or risk assessment that begets contingency planning using an "all hazards" approach to anticipate and respond to the potentially devastating extreme weather conditions believed to be attributable to climate change.

HRO and Viral Spillover and Spillback

One of the HRO principles applicable to infection prevention and disease control is preoccupation with failure—specifically, proactive risk management strategies to help anticipate and to identify potential for and actual spillover events. Clinicians should be vigilant and engage public health officials with urgency whenever they discern prognosticators that suggest that the populations they serve may be at risk of zoonotic infections.

Another HRO principle that can apply to addressing spillover is deference to expertise. For example, organizations should incorporate in their patient safety programs applicable governmental provisions designed to protect against animal-to-human transmission. For example, California's Title 8 §5199.1, "Aerosol Transmissible Diseases—Zoonotic," provides basic requirements for covered employers to establish, implement, and maintain effective procedures for preventing employee exposure to zoonotic aerosol transmissible pathogens.[31]

Another applicable HRO principle is resilience. During periods of uncertainty and crisis, promoting resiliency can take the form of continuous business operations planning and disaster recovery facilitation. Health care organizations have demonstrated and continue to demonstrate remarkable resiliency secondary to the global pandemic. Organizations must be agile and nimble, even as part of routine business strategic and tactical planning.

HRO and Poverty

In addition to a health crisis of historic proportions, the COVID-19 pandemic ushered in a global economic downturn. Primary diseases commonly associated with poverty, such as tuberculosis, malaria, and HIV/AIDS—and comorbid malnutrition—often target the more vulnerable populations in socioeconomically marginalized areas and in developing countries. Poverty is not just income deprivation but optimism deprivation.[32] In 2011, the CDC published its first *Health Disparities and Inequalities Report*, which examined health disparities—or differences in health outcomes—associated with groups of people "as defined by social, demographic, environmental, and geographic attributes."[33]

HROs' fervent commitment to a culture of safety includes making every effort to seek to understand social determinants of health (SDOH). Standardized, compassionate, and responsible approaches to addressing SDOH within an organization's or practitioner's control include discounted payment, charity care or other assistance to patients in meeting their financial obligation, and promoting awareness of patients' benefits coverage. Health care organizations can also institute internal policies that commit to supporting free clinics and eleemosynary organizations that provide emergency health care, food, and water.

Performance Measurement and Improvement

So, how does an organization know if high reliability and patient safety principles are truly embedded within its culture and are making a difference? Are things getting better, getting worse, or staying the same? According to Lord Kelvin, "When you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind."[34]

One key strategy for implementing HRO principles is to develop metrics for evaluating data reliability and to use data systems to measure the progress and efficacy of interventions. This strategy can help address needs related to open sharing of data and other information concerning safe, respectful, and reliable care and continually improving work processes and measuring progress over time.

Conclusion

High reliability is by no means the deus ex machina that will swoop down and vanquish all the world's chaos. But it is a portfolio of viable perspectives, tools, and ideas upon which a culture of safety can be built amidst what the Temptations described as a "ball of confusion" back in 1970.[35] And HRO is not some nebulous construct; it describes organizations comprising people who care enough to commit to making the world a better place.

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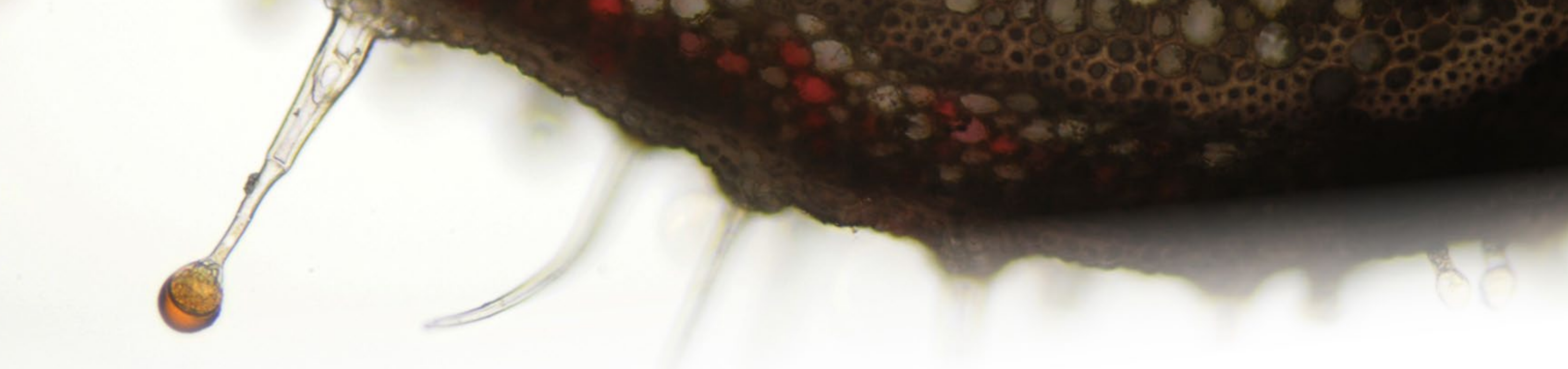

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HISTORY OF MEDICINE

How Racism and "Tropical Medicine" Built the Panama Canal

Jorie Braunold, MLIS

Abstract
At the turn of the 20th century, the physician William Gorgas led work that substantially mitigated mortality from mosquito-borne diseases among workers building the Panama Canal. The waterway launched the United States to political and economic superpower status by eliminating the need for risky maritime travel around the southern tip of South America, expediting exportation of US goods in international markets. Yet, as this article explains, innovations that curbed malaria and yellow fever were deeply rooted in racist foundations of capital and empire.

Conquest and Illness

During the late 19th and early 20th centuries, the United States looked to more extensively colonize the Caribbean and Pacific. The US victory in the Spanish-American War of 1898 compelled Spain to relinquish control of several territories, including Cuba. It was there that Drs Carlos Finlay, Walter Reed, and others proved that mosquitoes spread diseases. Acting on behalf of the US government in 1901, Dr William Gorgas campaigned to rid Cuba of mosquito-borne yellow fever, which was eliminated in Havana in 3 months.[1]

Based on the mosquito vector theory promoted by Finlay, Reed, and Dr Ronald Ross, Gorgas devised and led implementation of mosquito management strategies that facilitated the United States's role in the building the Panama Canal and in what Gorgas phrased as "conquest of the tropics for the white race."[2] Gorgas's racism is rarely discussed, but this article examines key ways in which his work on yellow fever and malaria perpetuated colonialism and white supremacy and was used to justify deep exploitation of Latin Americans and their lands.

Figure. Portrait of William C. Gorgas, Harris & Ewing, 1920

Reproduced from *World's Work*.[3]

Panama

Many tropical nations' ecological conditions exacerbate mosquito-borne disease incidence and prevalence. Panama's location between North and South America and between the Atlantic and Pacific Oceans, as well as visits from international investors looking to exploit its resources and global commercial value, geographically and historically positioned Panama to endure 400 years of yellow fever epidemics.[1] By the turn of the 20th century, Panama was weakly governed and believed by many to be indebted to the United States for support of its independence from Spain.[4] President Theodore Roosevelt seized on building the Panama Canal to showcase the United States' growing dominance in the western tropics. If the United States could conquer disease in Panama, it was thought, it would be closer to financially, technologically, and scientifically overpowering Europe on the global geopolitical stage.[5]

Prior to mosquito vector theory, Panama's ecology was reputed to be a "miasma" rife with "bad air," an untamed place hostile to White habitation.[6] A prominent 20th-century French engineer described Panama's climate and environment as "literally poisoned,"[6] which was thought by some to explain Indigenous Panamanians' alleged racial inferiority to persons in the Global North.[6] Notably, in the 1880s, the French tried to build a canal in Panama but were thwarted by French engineers' and Caribbean laborers' deaths from yellow fever and malaria. Strangely, US officials believed these diseases posed no risk that a "clean, healthy, moral American" could not solve.[7] Gorgas' mosquito elimination plan involved destroying mosquito breeding habitats, installing nets and screens, and dispensing quinine, but it was not immediately successful.[8] About 6 months after US workers' arrival on the isthmus, many died; a yellow fever epidemic had begun by November of 1904, causing the panic and flight of nearly three-fourths of US canal workers by January 1905.[1]

In many ways, infrastructure, such as hospitals and rail lines, built to support construction of the canal thwarted mosquito elimination. Prior to the 1904 to 1905 outbreak of yellow fever, the French, for example, built a then-state-of-the-art hospital to care for sick workers. But when French hospital workers, besieged by ants, placed bowls of water to drown them, the water became stagnant sites that nourished the hatching of mosquito larvae.[9] As US entomologist August Busck wrote: "[T]he progress of each steam shovel or of each of the extensive dumps produce[d] new [water drainage] problems."[10] Gorgas wrote in a 1907 *Journal of the American Medical Association* article that "if the conditions as they existed in 1905 were to continue, the canal would never be finished."[11] Control of mosquito-borne illness would require more funds and expanded oversight. At the request of Secretary of War William Taft,[3] then-American Medical Association President Dr Charles Reed guided production of a report on Panama that resulted in those 2 things. By spring of 1905, Gorgas would oversee the most expensive public health campaign up to that time in American history.[1]

Tropical Living as Healthy, Manifest Destiny

"The spread of civilisation," Gorgas believed, "is supposed to bring with it not only good ruling and justice, but also increased health and happiness. Apart from this moral aspect, it seems obvious, from a business point of view, that the opening up of the resources of an unhealthy country will never be a full success until that country is rendered healthy."[12] Public health and sanitation efforts in the United States focused almost exclusively on areas inhabited by White people, while Black, Asian, and Indigenous workers were left vulnerable to diseases under better control in many White communities. This inequity was exacerbated in "tropical medicine" when used to illustrate minoritized workers' alleged laziness and lack of hygiene that was, according to racial essentialist conceptions of contagion, causing diseases to spread. The racial essentialism expressed in tropical medicine justified displacement of Indigenous people living in tropical regions of the world and White people's conquest and occupation of their lands. According to this logic, White people were thought to be more suited to the tropics than Black, Brown, and Indigenous people because "As it becomes generally known that he [the White man] can live in the tropics and maintain his health, necessarily a large emigration will occur from the present civilized temperate regions to the tropics."[6] That is, it was not enough for a colonial power like the United States to extract natural resources from a place like Panama. Rather, "civilizing" the world required supplanting populations and rebuilding.

A public relations campaign launched by President Roosevelt was designed to introduce the world to a United States in control of its destiny, giving credence to the idea that "a technological mastery of nature helped define a nation's level of civilization."[6] It also reified the alleged supremacy of White people and underscored the alleged "languor" and "inefficiency" of minoritized peoples, which were believed to be inherent rather than "the inevitable concomitants of hot weather and tropical conditions generally."[13] As the chief of the US Bureau of Entomology wrote in an introduction to a book published in 1916, mosquito control in Panama was "an object lesson for the sanitarians of the world and has demonstrated the vitally important fact that it is possible for the white race to live healthfully in the tropics."[6]

Gorgas confidently envisioned that "within the next two or three centuries, tropical countries, which offer a much greater return for man's labour than do the temperate zones, will be settled up by the white races, and that again the centres of wealth, civilisation and population will be in the tropics, as they were in the dawn of man's history, rather than in the temperate zone, as at present."[11] In fact, he was known for his sweeping representation of the course of human progress in relation to climate and disease: "Clothing and fire, according to Gorgas, allowed the 'most vigorous and healthy races, mentally and physically' to migrate to temperate climates and escape the diseases which flourished in the tropics."[14] Only the "sanitary discoveries" of the early 20th century would allow the White man "to return from the temperate regions to which he was forced to migrate long ago, and again live and develop in his natural home, the tropics."[14]

Myths of tropical living as White destiny were also expressed in a 1906 speech by Roosevelt to Congress in which he said that sanitation officials in Panama should be "entitled to the same credit that we would give to the picked men of a victorious army."[15] Although Gorgas' success in controlling yellow fever and malaria was crucial to advancing the field that became known as tropical medicine and to completing the Panama Canal, it was also used to justify continued usurpation of Latin Americans' and Indigenous peoples' lands. As this article suggests, Gorgas' work should now be contextualized in a broader narrative of Western dominance and colonialism.

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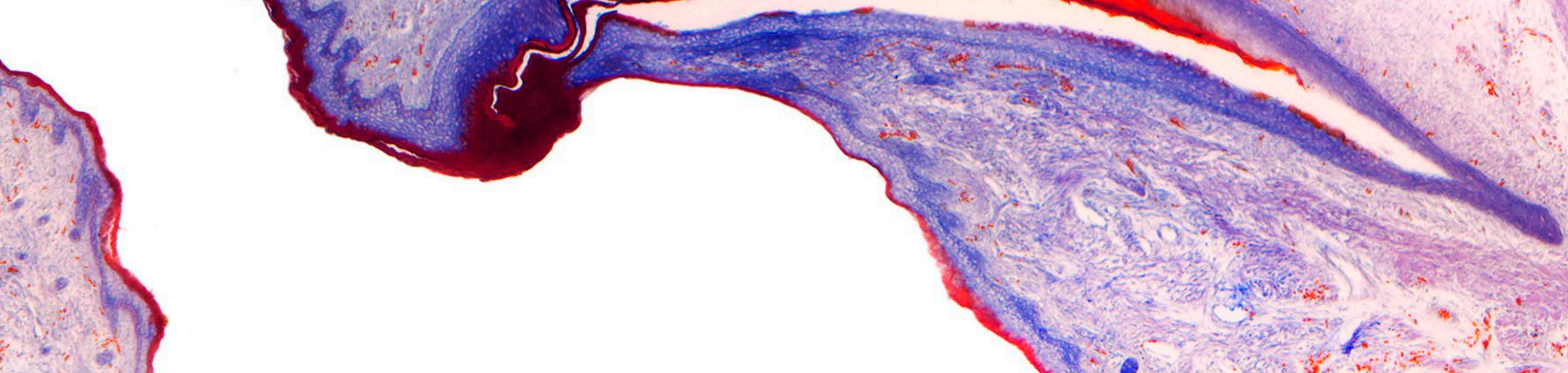

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VIEWPOINT: PEER-REVIEWED ARTICLE

How One Health Instrumentalizes Nonhuman Animals

L. Syd M Johnson, PhD, HEC-C, Hope Ferdowsian, MD, MPH, and Jessica Pierce, PhD

Abstract
This article interrogates anthropocentrism and nonhuman animal instrumentalization in One Health (OH). It argues that OH's approach to human health and zoonosis focuses too narrowly on furthering certain human interests at the expense of nonhuman animals, which is not sustainable, just, or compassionate. This article also offers an alternative vision for protecting and promoting health for all over the long term that includes the human right to self-determination and the nonhuman animal right to not be exploited or abused. This rights-based approach recognizes that the root causes of zoonosis should be identified and addressed via policies and actions that challenge nonhuman animal exploitation.

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Anthropocentrism in One Health

One Health (OH) is an approach to health that views the health of humans, nonhuman animals, and ecosystems as interconnected.[1] Conceptually, it emphasizes interdisciplinary approaches to global health challenges. The World Health Organization notes that OH "is particularly relevant for food and water safety, nutrition, the control of zoonoses … pollution management, and combatting antimicrobial resistance."[2] This statement of priorities is reflected in the growing literature on OH and pandemics, wherein the emphasis has often been on nonhuman animals as vectors of disease and resulting poor health for humans and on antimicrobial resistance and food-borne illnesses from the production and consumption of meat, dairy, and other animal products.[3,4]

In 2022, the Quadripartite—a partnership of the Food and Agriculture Organization of the United Nations, the United Nations Environment Programme, the World Health Organization, and the World Organisation for Animal Health—announced its 5-year One Health Joint Plan of Action to "collectively better prevent, predict, detect, and respond to health threats" and "improve the health of humans, animals, plants, and the environment, while contributing to sustainable development."[5] Notwithstanding these goals, the plan prioritizes zoonotic and vector-borne diseases that affect humans, food safety for humans, and antimicrobial resistance.[5] With the world still struggling with a global pandemic of zoonotic origin, these priorities are timely and necessary but also shortsighted. Indeed, OH has been criticized for viewing animal health through an anthropocentric frame of reference as a means to the end of human health.[6,7]

We start from an assumption that all animals, human and nonhuman, have basic rights to life, freedom, and the opportunity to flourish.[8,9,10,11] What those rights require on the ground varies by species depending on their needs and capacities, but, minimally, respecting the rights of animals assumes that their interests and lives are not automatically subjugated to human interests. The stated goals of OH are consistent with our assumption. Nevertheless, although OH approaches commonly mention animal welfare, they have given minimal attention to animal health for the sake of animals.[10,12] The anthropocentrism for which OH has been criticized instrumentalizes animals by recognizing their value only insofar as it contributes to human flourishing, thereby reinforcing the very anthropocentrism that justifies exploitation of farmed animals, encroachment on animal habitats, and the wildlife trade that OH purports to address. Like these exploitative practices, an anthropocentric OH accepts animal suffering if it serves specific human-centered goals, and it challenges harmful and exploitative practices only insofar as they fail to serve human-centered goals. Thus, threats posed by climate change to wild animal populations and threats to the climate from large-scale animal agriculture are important within OH approaches primarily because they have negative effects for humans—including health effects and threats to property and financial interests—and not because they cause significant harm to animals and destroy their habitats. Because OH approaches generally lack an ethical framework[13,14] through which to view health in the context of rights and interspecies justice, they fail to recognize that animals have moral claims to health and well-being in their own right.

One Health and Zoonotic Disease

The OH approach to preventing zoonotic diseases is instructive. Zoonoses occur through human interaction with animals, such as through intensive animal farming practices; through human encroachment on and exploitation of the natural habitats of animals; and through the capture, transport, export, and confinement of animals for human use and consumption.[15,16] Capps et al argue that within an anthropocentric OH framework, strategies for responding to zoonotic pandemics “have tended to map mechanisms of disease transmission, and identify problems and solutions from the standpoint of human interests.”[17] Culling animals to protect supposed human interests is one example. On average, hundreds of thousands of animals are killed each day to control zoonotic outbreaks.[17,18,19]

The 2022 to 2023 outbreak of a highly pathogenic avian influenza has prompted the killing of tens of millions of farmed birds, including millions of healthy birds, in the United States.[20] In Spain, more than 50 000 farmed mink were killed after an outbreak of H5N1 avian influenza,[21] and tens of millions of farmed mink were gassed to death in the Netherlands after SARS-CoV-2 was detected on fur farms.[22] In Norway, beginning in 2015, an attempt to stop the spread of livestock-associated methicillin-resistant *Staphylococcus aureus* (LA-MRSA) resulted in the culling of all pigs on farms where LA-MRSA was detected.[23] It should be underscored that LA-MRSA is not a health threat to pigs. Rather, Norwegian health authorities sought to avoid hospital-acquired LA-MRSA infections introduced by farm worker patients infected through their work.[24] (Ironically, it was also farm workers who introduced LA-MRSA infections to pigs.[24]) This “search and destroy policy" was viewed as cost-effective because the overall prevalence of LA-MRSA on Norwegian pig farms was low, while the cost of prevention in hospitals was high.[25] None of these animals were killed for their own sake—many were not infected—but rather to limit threats to human health and economic interests. By contrast, in the Netherlands, where the prevalence of LA-MRSA in pig herds was close to 70%, culling would have been financially harmful for the pig industry and thus was not adopted.[24]

The US Agency for International Development describes its One Health approach to preventing zoonosis through bat-borne Nipah virus among pigs in Thailand in stark economic terms,[26] while also making spurious claims about the role of animal agriculture in food security.[27,28] (Numerous studies have demonstrated that global food security is better addressed through plant-based agriculture because of land, grain, and water inefficiencies associated with animal agriculture.[28]) By linking pig farms via app to a national surveillance database, the agency claims that "140,000 pig farms in Thailand are continuously monitoring disease risk, providing an early warning for spillover of viruses and improving farm biosecurity and management. By safeguarding the more than $3 billion pork industry, this app is contributing to Thailand's food security, economic stability, and livelihoods."[26] Reflecting on an analogous situation in which the United Kingdom culled badgers to prevent the spread of bovine tuberculosis in farmed cattle, Lederman et al argue that culling not only violates the interests and denies the moral value of individual animals, but also "arguably fails to consider the inherent value of ecosystems … and how the interests of other living beings are affected by the absence of badgers."[18]

Toward a Rights-Based Ethical Framework

Without an ethical framework that values animal life and flourishing, OH can only trivially recognize that human, nonhuman, and environmental health are interconnected. It is thus hard to see how OH in practice is distinct from traditional public health approaches that focus on the health of human populations.[17,24,29] An OH approach to zoonoses that emphasizes the protection of animal-exploiting industries does not and cannot interrogate the root causes of zoonoses and pandemics—the subjugation of animal rights to a subset of human interests. As long as OH remains narrowly and anthropocentrically focused—as long, as Garnier et al note, as a "development paradigm, prioritizing the pursuit of wealth and food security"[14] dominates—it will be unable to challenge unjust and unethical practices and will struggle to implement a morally sustainable, fair, and compassionate paradigm for addressing the climate, biodiversity, and health crises that threaten all species.[28] The limitations of an anthropocentric OH mean it can only tinker around the edges of systemic and complex problems without addressing the real and pressing core issues. By viewing animals merely as threats to (or a means to) human health, it fails to appreciate how human activities pose a profound threat to all life.

Lederman et al argue that a "One Health ethics" already contains the tools to move from "an anthropocentric approach to disease" toward one that can take into account "the interests of animals, all living things or the biotic community as a whole."[18] An OH approach that foregrounds justice (sometimes called Just One Health) asserts that humans and other animals have rights not to be subject to exploitation and abuse and calls for policies and actions that advance interspecies justice.[30] Foregrounding justice in OH provides tools for exposing the root causes of challenges like zoonosis and climate change in human activities that exploit not only animals and ecosystems, but also marginalized humans.[10,29,31] As an example, an ethically grounded and just approach to zoonosis that recognizes that animals have their own rights and interests—their own claims to justice—would prioritize prevention of zoonotic outbreaks by tackling their roots: the exploitation, industrialization, and moral instrumentalization of animals by humans. This approach might be operationalized by, for example, phasing out industrialized farming practices—including the transport, import, and export of billions of farmed animals—that drive problems like antimicrobial resistance, food-borne illness, and zoonoses. It would acknowledge that the destruction of rainforests and other habitats is driven by the world's appetite for cheap meat[32] and that this destruction is fundamentally unjust: it accelerates climate change, endangers wildlife, and harms marginalized Indigenous peoples by destroying the lands on which they live.[33]

An OH framework that recognizes and respects the rights of life, freedom, and flourishing for animals and *all* humans must confront the reality that problems like climate change and zoonotic pandemics cannot be controlled or limited by select human-centered solutions because, fundamentally, privileged humans and their interests are the problem.[34] By foregrounding ethics and justice, unjust trade-offs like culling, which sacrifice animal lives for economic interests, can be interrogated, along with the tolerance for the instrumentalization and exploitation of animals *and* humans within OH. Doing so would enhance the ability of OH to fully realize the goal of approaching problems like zoonoses holistically, systemically, structurally, and sustainably by recognizing that animal and human interests in health, life, and flourishing are only advanced by solutions that promote rights and justice for everyone.

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VIEWPOINT

Lessons for Ethics From the Kingdom of Fungi

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Abstract
This article considers lessons about American (individual-centered) anthropocentric (human-centered) thinking that can be applied to how we confer dignity and moral status to beings other than humans. Interestingly, global bioethics might glean such lessons from fungi.

Mushrooms in the Moment

Mushrooms are having a cultural moment. Last year on Halloween, I dispensed wee chocolate bars to an adorable 4-year-old dressed as *Amanita muscaria*, a kind of mushroom often represented in fairytales as “toadstools” easily recognized by their white-spotted red caps and white stems.[1] The fact that some fungi, including this one, produce psilocybin is probably another socially relevant reason why mushrooms appear on various fabrics and at our doors for trick-or-treat. There are also ecological reasons to conjure wider recognition of the importance of fungi and other beings with which we co-inhabit the world.

Networks

Mycelia give literal, physical structure to human existence by forging underground linkages among roots and through soils in diverse ecologies in which human and nonhuman animals, plants, fungi, and other microbes (eg, bacteria and viruses) are enmeshed. A single mushroom is one fruiting body—a fungal flower, one might say—that grows from a larger, mostly underground, mycelial network known by some as the “wood wide web.”[2] A mushroom’s appearance as a discrete entity seems to perpetuate what we might construe as a particularly American—prone to be hyper individualist—kind of anthropocentric (human-centered) illusion that these organisms’ most prominent form of selfhood emerges and exists in the world as an individual and as mainly for human benefit. But, really, fungi can be huge communities that benefit many species.

Perhaps it’s worthwhile to indulge our tendency toward anthropocentrism for a moment to consider how humans specifically benefit from fungi. Fungi are among the many microbes that enable us to live by inhabiting our guts and other sites in and on our bodies. Fungi can also inhabit or host other organisms that flourish in and on each other.[2] We rely on and are part of these networks, despite our nodes of interconnection remaining invisible, unknown, or unbelievable.

Questions fungi prompt humans to ask include:

1. *What does it mean, ecologically and ethically, to be an individual?*
2. *What are the most ecologically important consequences of an American anthropocentric tendency in ethical reasoning to confer dignity or other kinds of moral standing on individuals rather than on communities and on humans rather than on a broader range of species?*

Dignity

One lesson for humans, especially those of us working in health care ethics, from fungi—and from One Health, a key theme of this February 2024 theme issue—is that we might do better as a species to think of many, if not all, fungi, plants, and nonhuman animals as having dignity because they have places in the world, because they inhabit ecological niches. If species' members' ecological niches are viewed as key ethical sources of their and our dignity, we can more robustly acknowledge how the needs of the landscapes we co-inhabit underlie our pressing need to be humble about our limited capacity to respond to our shared problems, especially existential ones, as a collective.

Humans have much to learn from other species about collective intelligence, for example. Many bird species have evolved in ecological niches to express collective intelligence that humans have not evolved to express. Snowy owls reliably regulate their reproduction trends according to availability of resources, particularly lemmings.[3] Humans, however, tend to think of reproductive responsibility mainly in terms of individual family resource access, a kind of reasoning with ecological impact far beyond individual family units. Other bird species, such as European starlings, and many fish have evolved group-based aerial or aquatic coordinated movement—called *murmuration*—that protects most in their flocks or schools from predation.[4] Humans can collectively choreograph for the sake of music, dance, labor strikes, or military operations, but our track record of success in coordinating group actions that motivate resource or survival interests for *most of our species* is not well established, especially in the years following large-scale, intentional decimation of First Nation ways of being in the world.

And there are more good reasons to consider expanding dignity's scope of applicability beyond humans. But first, of course, there's a good question we need to ask about such expansion: *Should we regard* Candida auris*,* anopheles *mosquitoes, or head lice as beings with dignity or as beings with some other kind of ethical value, as ends in themselves?* Despite anthropocentrism's obvious speciesism, we must give anthropocentrism its due, if only because it has, unsurprisingly, motivated gains in human health. Perhaps anthropocentrism serves a purpose of reminding us that if we enlarge dignity's tent to accommodate the interests and stakes of more and a more diverse range of beings, then we must also think carefully about the nature and scope of legal rights, ethical goods, and just deserts that dignity confers on so many beings.

Yet, it need not follow from expanding dignity's tent that everyone or everything under that tent deserves the same expressions of respect for their dignity in different circumstances. What does follow is that we are obliged to carefully consider how we assign the legal rights, ethical goods, and just deserts of dignity, to which organisms, when, and why. A caution, to be clear, is that, as a species, humans can probably no longer afford to see their health interests through anthropocentrism's microscopic, myopic lens. Despite its advantages to humans, anthropocentrism has become its own threat to humans' continued existence. One reason for this is that human health does not, has not, and never will stand on its own. Our health relies on ecological well-being, even when we don't know it or believe it.

Humility

Let's suppose a likely case that illustrates the irrelevance of what humans know or believe about their own health: there's a microbe yet unknown to science with key functions in Earth's ecosystems that are also yet unknown.[5] In the absence of ecological knowledge about Earth's communities' everyday operations, even the staunchest anthropocentrist has good practical reasons (eg, what you don't know might hurt you, what you don't know now but learn later could help you) to broaden conceptions of dignity to a broader range of beings with which we live. Even in the case of a microbe known to pose human pathogenicity, if that microbe has known or even unknown roles in Earth's ecosystems, the ethical and intellectual value of *epistemic humility*—respect for what we don't know or know little about—helps us discern what would still be those same practical reasons to center human health in our reasoning about which beings we confer dignity on.

We Owe Beings We Don't Know

An ethical and ecological merit of expanding eligibility for dignity is that, even when such pathogens threaten humans or our livelihoods, if such organisms have evolved to occupy important ecological niches or to occupy ecological niches whose importance is unknown to us, we should ask, *What are the smartest ways for us as a species to express epistemic humility?* It could be that expressions of epistemic humility and expressions of respect for the dignity of our ecological co-inhabitants turn out over time to be ethically and ecologically convergent. If we fail to express epistemic humility in our reasoning about dignity, we ought to be worried about what that says about our individual characters in addition to its consequences for our communities and species. At the very least, the limited scope of what little humans know about our microbial co-inhabitants' lives does not seem to justify the scope of decimation we've wrought on fellow species to motivate the ends and interests of humans, especially a few humans of great privilege.

If and when we do learn to express more thoroughgoing respect than we have in the past for our enmeshment, for our "entangled life," in the words of the biologist Merlin Sheldrake,[2] then we equip ourselves to more fully and powerfully think about and enact what we owe each other and what we owe all beings of ethical and ecological value, known and unknown, as we try to make good in and on the exchanges global bioethics requires.

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