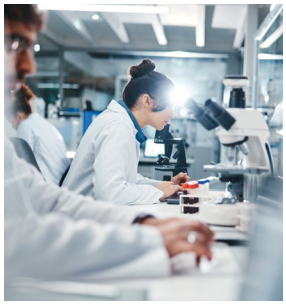

3

One Health: A Comprehensive Approach to Improving Global Health in a Changing World

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ABSTRACT

The world is facing interconnected crises: pandemics, inequities, climate change, and biodiversity loss. The One Health approach, recognizing links between human, animal, plant, and environmental health, offers solutions. Benefits include reducing zoonotic risks and improving surveillance through collaboration, equity, and stakeholder engagement. Endorsed internationally, the approach has recognized economic benefits through prevention. Consistent integration, capacity building, interdisciplinary teamwork, and Indigenous knowledge inclusion are crucial, and expanding the application to address antimicrobial resistance and food systems is necessary. Recognizing interdependencies and multisectoral cooperation through a One Health lens can lead to efficient and equitable solutions and contribute to sustainable development.

THE ONE HEALTH APPROACH

Our world is facing critical and converging crises that can no longer be ignored. Attempts to control deadly viruses—such as Middle East respiratory syndrome (MERS) coronavirus, severe acute respiratory syndrome (SARS)-related coronaviruses, and pandemic influenza viruses—have been, out of necessity, almost entirely reactionary. Because of recent devastating events, the world is poised to move beyond that costly approach, which measures impact in death tolls and money spent on diagnosis, treatment, and containment. The time is right for a more proactive paradigm that allows for use of knowledge on what diseases might

be emerging and the development of interventions to prevent or at least control the pathogens at their source.

Before the COVID-19 (coronavirus) pandemic, the World Bank (2012) documented that, from 1997 to 2009, at least US$80 billion was spent responding to just six outbreaks of deadly zoonotic diseases, caused by viruses shared between people and animals. It also estimated that a pandemic would reach costs above a trillion US dollars. As evidenced by the COVID-19 crisis, forecasts not only were correctly cautionary but also far underestimated actual costs; they did not begin to anticipate the long-term costs to economies and societies of a severe pandemic.

For decades, scientists and policy makers have advocated for the One Health approach and proactive surveillance to identify all viruses of pandemic risk. They foresaw a relatively modest global cost of US$4 billion, should that work have been conducted and the data used to prepare for a SARS-related coronavirus outbreak in advance (Carroll et al. 2018). Application of One Health approaches could drastically reduce economic and human losses as the public health community drives surveillance and interventions upstream and predicts the risk from these diseases before they emerge.

In addition to recurring epidemics and pandemic threats, we face many interrelated and escalating societal challenges, such as equity and justice, clearly illustrated by disparities in access to health services among and within countries, as well as unjust food systems that fail to equitably deliver nutrition and thus health resilience. The planet itself faces a climate change crisis and an unprecedented loss of ecosystems and biodiversity that humans are—or should be—racing to slow. Current proposed actions to address these challenges are most often siloed, addressing only the clear and specific causes of a single crisis, or the symptom(s) of one, without holistic examination of the inextricably linked drivers of these challenges and thus without the identification of implementable solutions that address the complexity of the current global situation. In addition, single-problem approaches often fail to acknowledge human behavior as the root of all of these problems and human behavior change as the only real solution. If we cannot stop these accelerating processes before we reach identifiable tipping points, life on earth could fundamentally change for us all (Rockström et al. 2009). At the highest levels of international policy making, organizations and confederations such as the World Bank and World Health Organization (WHO), and now the Group of Seven and Group of Twenty, have all begun to advocate for a more integrated approach to health and climate policy—One Health.

Multisectoral collaboration has long been recognized as important for health outcomes (Watkins et al. 2017). The concept of One Health, however, directly acknowledges the connections among the health of humans, animals, plants, and the environment and prioritizes relevant outcomes for each. In 2021, a harmonized definition developed by the One Health High-Level Expert Panel was endorsed by the four organizations that now form the "Quadripartite" (the Food and Agriculture

Organization of the United Nations [FAO], the United Nations Environment Programme [UNEP], WHO, and the World Organisation for Animal Health [WOAH], founded as the Office International des Epizooties [OIE]):

> **One Health** is an integrated, unifying approach that aims to sustainably balance and optimize the health of people, animals and ecosystems. It recognizes the health of humans, domestic and wild animals, plants, and the wider environment (including ecosystems) are closely linked and inter-dependent. The approach mobilizes multiple sectors, disciplines and communities at varying levels of society to work together to foster well-being and tackle threats to health and ecosystems, while addressing the collective need for clean water, energy and air, safe and nutritious food, taking action on climate change, and contributing to sustainable development (OHHLEP et al. 2022). [Emphasis in original.]

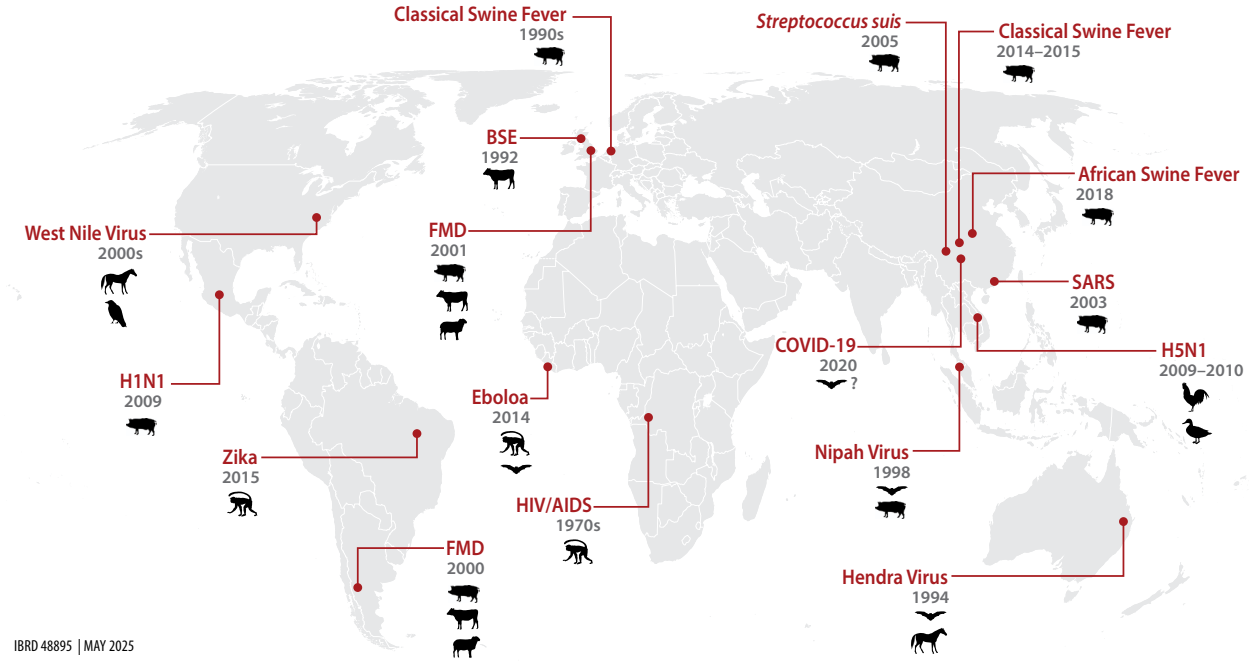
The definition is accompanied by underlying principles that reinforce the importance of reducing trade-offs and increasing co-benefits, including through equity, sociopolitical parity, the notion of a socioecological equilibrium, stewardship, and transdisciplinarity and inclusion of stakeholder voices including traditional knowledge forms (OHHLEP et al. 2022).

Similar to equity concerns in other domains, guidance for ethical use and governance is often established without inclusion of all appropriate marginalized communities and does not always include consideration of sovereign rights. Like all nation states, Indigenous Tribal/Nation governing entities require reliable, relevant, and current data to make sensible health policy decisions (Barrett et al. 2022). International frameworks (for example, the Convention on Biological Diversity, Cartagena Protocol on Biosafety, and Nagoya Protocol) and a series of legal instruments have been developed to inform, operationalize, and protect Indigenous Peoples' rights to free, prior, and informed consent—a specific right that pertains to Indigenous Peoples. The United Nations Declaration on the Rights of Indigenous Peoples reaffirms and asserts Indigenous Peoples' rights to self-governance and self-determination over their collection, use, and ownership of data (FAO 2016; United Nations 2007). These rights, coupled with the universal right to self-determination, are the foundation to give and withhold consent to participate in research projects, promote equitable participation, and protect Indigenous knowledge in light of the open science/open data movement. Despite the identification of Indigenous data stewardship practices (refer to Carroll et al. 2021), digital platforms, big data, and open science databases present new international challenges and further inequities (Ross-Hellauer 2022). For instance, the use of digital tools requires technical capacity and resources to ensure protection of confidential information and health identifiers, especially during health crises (Hiraldo, James, and Carroll 2021; Johnson et al. 2021). Indigenous and other marginalized communities often face health data invisibility because of a lack of data collection and because of bias or misrepresentation resulting from data collection using a "deficit" lens, which reinforces dysfunction and marginalization (Barrett et al. 2022).

Although the One Health concept dates back to the time of Hippocrates, historians have described the modern history of One Health (Woods et al. 2017), tracing the

term "One World-One Health" to the Wildlife Conservation Society's Manahattan principles of 2003. "One Health" as a term appeared for the first time in the biomedical literature in 2005 (Zinsstag et al. 2005). The approach gained traction as a unifying international paradigm during a pre-COVID-19 time of global crisis, when the international public health community had concerns that the avian influenza A (H5N1) virus, identified in Asia and spreading across continents, would spark a pandemic of severe disease in people and the food supply. Further, this influenza A (H5N1) virus emerged at a time of already-high global health concerns about other zoonotic disease, caused by pathogens shared by people and animals. For myriad reasons, including disruption of previously stable ecosystems and better surveillance and disease detection capacity in countries, there had been increasing reports of outbreaks of new zoonotic disease pathogens, such as bovine spongiform encephalopathy, SARS-related coronaviruses, influenza A (H5N1) virus, influenza A (H1N1) virus, and henipaviruses; reemerging zoonotic pathogens, such as Rift Valley Fever Virus, ebolaviruses, Zika Virus, and West Nile Virus; foodborne diseases; and antimicrobial resistance (AMR) (map 3.1).

Map 3.1 Notable Disease Outbreaks and Pathogen Emergence and Key Animals Involved in Disease Transmission, by Year



Source: Adapted from Patterson et al. 2020.

Note: BSE = bovine spongiform encephalitis; COVID-19 = coronavirus disease 2019; FMD = foot and mouth disease; HIV/AIDS = human immunodeficiency virus and acquired immune deficiency syndrome; SARS = severe acute respiratory syndrome.

In this context, the Tripartite (the One Health platform initially explored by WHO, WOAH, and FAO in 2008 and formalized in 2010) and global health partners, including the World Bank and the newly established United Nations System Influenza Coordination office, convened a series of meetings beginning in 2005. These International Ministerial Conferences on Avian and Pandemic Influenza brought together ministers primarily from the animal health and public health sectors to discuss and agree on the need for intersectoral action to reduce national and global risks from this and other zoonotic influenza viruses (UNSIC and World Bank 2010). In 2008, at the meeting in Sharm el Sheikh, the group broadened the scope to include other emerging and endemic zoonotic diseases in line with the new framework "Contributing to One World, One Health: A Strategic Framework for Reducing Risks of Infectious Diseases at the Animal–Human–Ecosystems Interface" (World Bank et al. 2008). International convenings continued as part of the Global Health Security Agenda and as instigated by large-scale projects, such as those supported by the US Agency for International Development. The term "One Health" began to be widely used to describe the new international policy recommendation of working across sectors and disciplines to address influenza and other zoonotic diseases and AMR. A clear definition of One Health as added value of a closer cooperation between human and animal health was proposed in 2015 (Zinsstag et al. 2015), showing incremental benefits of joint human and animal vaccinations in pastoralist settings in Chad (Schelling et al. 2005) and incremental benefits of zoonoses control (refer to table 3.1).

The new policies and funding established by the World Bank and other development partners sparked an exponential increase in activities using this newly recognized collaborative, multisectoral approach. Many countries have established national mechanisms for coordination using the One Health approach, and ministries now routinely work together on operational activities. They have a variety of tools and processes to support implementation and assessment of One Health capacity, infrastructure, and activities available to them (Pelican et al. 2019; WHO, FAO, and OIE 2019).[1] In 2022, UNEP formally joined the Tripartite, creating the Quadripartite (FAO et al. 2022).

Despite mainstreaming of One Health policy and gains in multisectoral collaboration at the international level and in some countries, especially between the public health and animal health sectors, functional capacity to identify new emerging diseases, especially those evolving in animals, is still limited. We may never truly know the timeline, geography, and species involved in the emergence of the SARS-CoV-2 virus. We do know, however, that global capacity to address the emergence and spillover of novel viruses into humans or into new animal hosts that could act as reservoirs for human exposure, as well as those that could be vulnerable to losses that could severely affect the human food supply, is weak. Since the emergence of SARS-CoV-2, other pathogens have similarly emerged or reemerged, including mpox virus and influenza A (H5N1) virus, with devastating consequences in human and animal populations. These viruses illustrate the ongoing threats from zoonotic pathogens and reinforce the need to change the way we approach

their management (FAO 2023; WHO 2022). A handful of large-scale projects have provided the proof of concept that viruses of concern can be identified and ranked for risk mitigating action. Before the COVID-19 pandemic, however, the lack of a global agreement to pursue preparedness left global society's fate in the hands of disconnected public health systems not designed to handle a pandemic caused by a novel disease, now designated as Disease X (Carroll et al. 2018; Grange et al. 2021; PREDICT Consortium 2020).

Working across sectors on surveillance is critical, including sharing information that may increase vigilance and that could provide early alerts of a pending threat; however, simply working together using mainstream scientific approaches to public and animal health is insufficient. We must begin to understand and more holistically address the complexity of the broader social, cultural, and ecological systems involved in disease emergence and control and consider the potential for spillover events in the contexts in which they occur (Daszak, Cunningham, and Hyatt 2000; Kelly et al. 2017; Mumford 2023). Specific efforts to better empower rural and suburban municipalities and include community-based organizations and social scientists, who can help with effective communication and combat misinformation, are essential, as evidenced by the dramatic losses, measured in lives and financial damages, resulting from societal choices and human behavior in response to the COVID-19 pandemic.

WHY USE A ONE HEALTH FRAMEWORK?

One Health offers not only a theoretical construct but also a practical, solution-oriented approach providing added value over those that do not recognize the interconnected nature of health. Although providing a general structure for collaboration, application of the One Health approach is context specific. Accordingly, the objectives, stakeholders, information needs, and strategies will differ with the particular issues under consideration and local context (Berger-Gonzalez et al. 2020). At the beginning of a process to address a complex problem, the One Health approach can help determine who needs to be at the table and the most efficient and effective ways to address an issue or to pursue a desired outcome (Berthe et al. 2018).

The application of One Health in numerous contexts has resulted in an existing and growing body of knowledge. For example, the development and use of a "Living Safely with Bats" visual booklet supported a One Health approach to risk communication and community education in villages and primary schools in over 20 countries. It increased knowledge about practical strategies for reducing zoonotic disease risks in daily living, while protecting bats and the important ecosystem services they provide in African and Asian countries (Martinez et al. 2022). Monitoring and detection of disease in animals have also helped inform alerts or other action to reduce public health risk. For example, investigation of reports of howler monkey deaths in Bolivia led to detection of Yellow Fever virus

circulation and a preventive vaccination campaign in humans (Kelly et al. 2020). Similarly, One Health surveillance has been enhanced within and across countries through regional networking approaches; for example, the MATRIX project on foodborne pathogens and emerging health threats in 12 European countries, funded by the One Health European Joint Programme and the PREDICT project, supported systems strengthening for emerging infectious diseases in 30 countries across Africa and Southeast Asia. Although these case studies show the potential value addition from such an approach, the systems to routinely collect and use this information more systematically across disciplines, sectors, and stakeholders are not widely in place.

Countries are increasingly developing national One Health coordination mechanisms or platforms that provide a multisectoral coordination for ministries and a wider group of stakeholders. In Liberia, for example, a platform was launched in 2016 with a governance manual and five Technical Working Groups; chairing of the platform by the Vice President provided high-level political support. In addition to a goal of more frequent and routine sharing of information and collaboration, these platforms have been mobilized during disease events and in the planning and implementation of strategies. For example, in Tanzania, One Health Rapid Response Teams have been established at the district and regional levels to promote multisectoral disease investigation and outbreak control (Mtui-Malamsha et al. 2020). With national platforms in place, many countries are now working to enable subnational coordination. The establishment of similar coordination mechanisms at the country and regional levels is part of the indicators of projects, such as the World Bank–supported Regional Disease Surveillance Systems Enhancement for West and Central Africa.

The One Health approach also appears to be gaining traction from key commitments by other sectors. For example, the Global Biodiversity Framework adopted by parties to the Convention of Biological Diversity in 2022 states the value of One Health and other integrated approaches to help meet its 23 targets, which span aspects of ecosystem protection, conservation of biodiversity, and prevention of spillover. As power imbalances across ministries remain and must be further addressed, financing mechanisms must be designed to support implementation and to broaden the source of investments and the recipients contributing to One Health. This One Health implementation, in turn, will help support a whole of government and ideally a whole of society approach.

THE ECONOMIC CASE FOR ONE HEALTH

The economic case for One Health is based on the assumption that closer cooperation between human and animal health and other sectors leads to incremental net benefits that cannot be achieved if the sectors work in isolation (Zinsstag et al. 2015). All the same, such collaborations across the different sectors and disciplines come with costs that need to be understood, described, and

estimated, as well as a stream of benefits from improved overall health management and better efficiencies in resource management (Rushton et al. 2012). To prove incremental benefits of a closer cooperation, novel methods must establish the effect of the interventions at the environmental-animal-human interface through statistical or mathematical models that are combined with cross-sectoral economic analyses (refer to example in figure 3.1). A difficulty with such work is the need to estimate crises that do not happen because a One Health approach embodies preventive rather than curative health management.

Given that One Health is an approach, the ways it can be applied and situations in which it could be useful are numerous. Therefore, generating evidence of benefit will always require some interpretation in the specific context. Despite the desperate need for much better systematic understanding of the role of individual ministries and subnational stakeholders in the policy process and analyses of political economy and associated power (Garritzmann and Siderius 2024), good practices are increasingly becoming visible. Such good practices include stakeholder analysis and consultation to ensure sufficient engagement of those who need to be at the table and part of co-design or implementation (table 3.1).

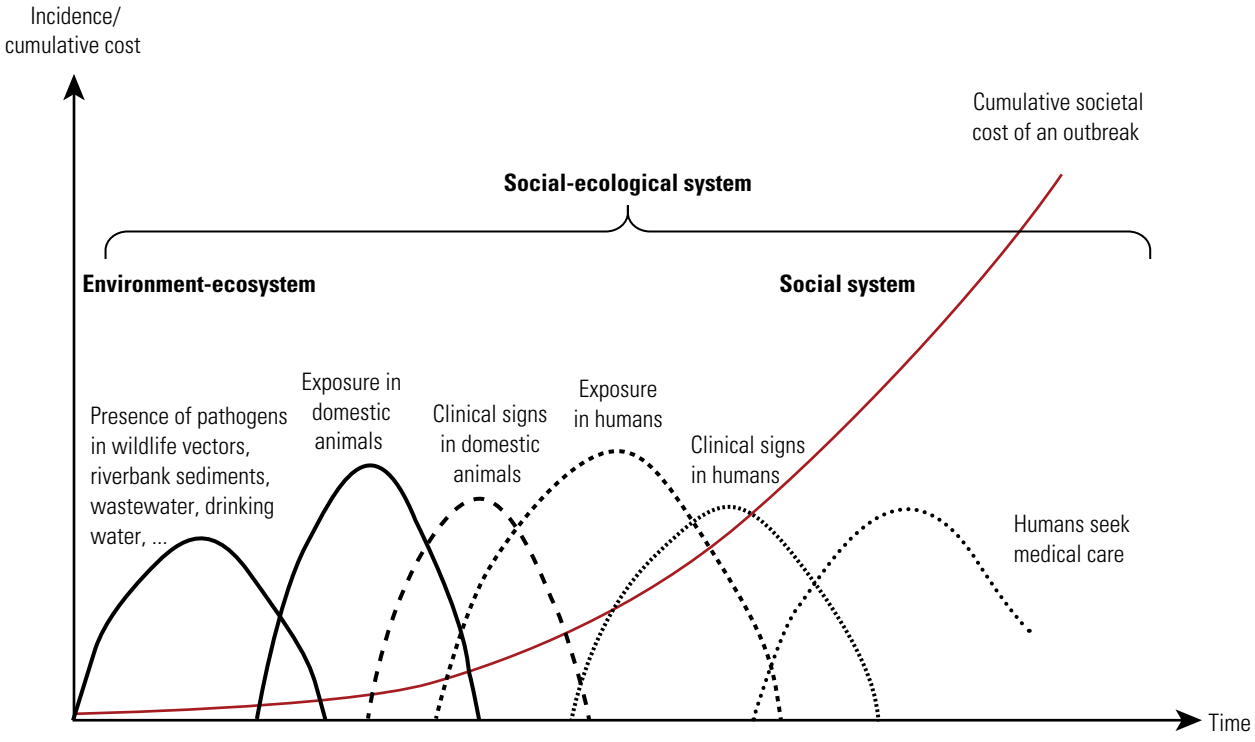
Table 3.1 Studies Examining the Benefits of Disease Prevention through a One Health Approach

Study topic	Key finding	Source
Strengthening human and animal systems	US$1.9 billion to US$3.4 billion per year invested in building up human and animal health system yields. >US$30 billion annually in avoided costs of epidemics, based on costs of major zoonotic diseases incurred between 1997 and 2009.	World Bank 2012
Joint vaccination services for animals and humans	Joint vaccination of animals and humans in pastoralist areas of Chad saves 15 percent of the operation cost, compared to separate services.	Schelling et al. 2005
Brucellosis vaccination in livestock	Societal benefits from mass vaccination of livestock to control brucellosis in Mongolia are three times higher than the intervention cost (figure 3.2).	Roth et al. 2003; Zinsstag et al. 2005
Rabies vaccination in dogs	The cumulative cost of mass vaccination of dogs at 70 percent coverage and postexposure prophylaxis is lower than human postexposure prophyslaxis alone in 10-year period.	Mindekem et al. 2017
Benefit-cost analysis of eliminating rabies in Africa	Coordinated mass dog vaccination between countries and PEP would lead to the elimination of canine rabies in Africa, with a total welfare gain of US$9.5 billion (95 percent CI: 8.1 billion to 11.4 billion). Uncoordinated mass vaccination of dogs between countries and incomplete PEP in humans result in lower welfare gains and do not lead to the elimination of canine rabies.	Bucher et al. 2023
Assessing socioeconomic impacts of infectious diseases using a multisector approach	Case studies of Ebola virus disease, Zika virus infection, and others identify wider socioeconomic consequences than traditional public health costs and identify private sector organizations as important and underrecognized stakeholders.	Smith et al. 2019

Source: Original table compiled for this publication using the indicated sources.

Note: CI = confidence interval; PEP = post-exposure prophylaxis.

Figure 3.1 Schematic Relationship of Time to Detection of an Emerging Pathogen and Its Cumulative Cost of Control



Source: Adapted and expanded by Zinsstag, Utzinger et al. 2020 from World Bank 2012.

IDENTIFYING NONFINANCIAL METRICS

Elinor Ostrom (2015, 15) notes in *Governing the Commons*, "We can consider freedom of disease in its non-rivalrous and non-excludable quality as a common or public good." By analogy, unhindered spread of disease, leading to outbreaks, or endemic stable transmission of disease can be considered a "tragedy of the commons," as described by Garrett Hardin (Zinsstag, Schelling, et al. 2020, chapter 31).

Local and Global Public Goods

Reducing pandemic risk—although a global public good—requires local actions to curb spillover risk and prevent local outbreaks from spreading. Demonstrating impact at national and local levels may resonate in national and subnational budgets. Investments in One Health–based prevention, detection, response, and recovery can generate local and global public goods relevant for domestic financing. As with other avoided illness or avoided events, however, intervening on pandemic risk, in terms of likelihood or impact, may be considered to have an invisible value of prevention that makes it unattractive for financing and measurement at a national level when considered in isolation. Thus, existing co-benefits may offer more amenable options

as a starting point for measurement; in some cases, they can be considered a good proxy for overall systems strengthening that also have broader effects of reduced disease risk. Such metrics must be identified and agreed upon in order to help track outcomes, refine approaches as needed, and demonstrate value for society as well as return on money invested.

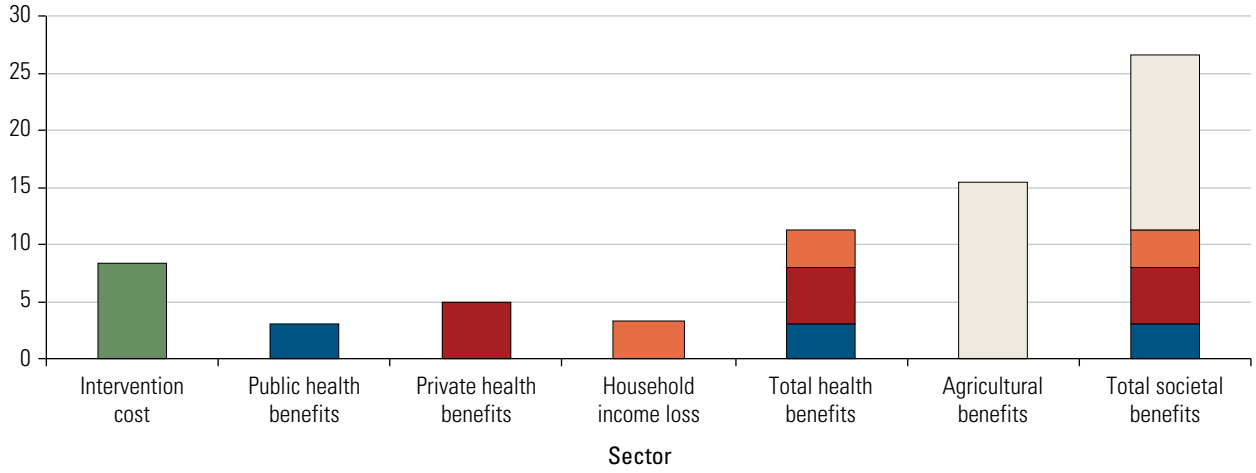
Timeliness metrics provide an example of a practical evaluation tool designed to strengthen public and animal health systems by assessing outbreak performance. Strengthening capacities ahead of outbreaks and tracking and measuring the time between key outbreak detection and response milestones provide countries and regions with a systematic and quantifiable method to identify gaps that can be targeted for improvement. Several timeliness metrics frameworks have been proposed, including the One Health timeliness metrics (Salzburg Global Seminar 2020), the 7-1-7 targets piloted by Resolve to Save Lives (Frieden et al. 2021), and the Joint External Evaluations (refer to chapter 5) under the International Health Regulations Monitoring and Evaluation Framework (WHO 2016). The WHO Regional Office for Africa recently adopted the 7-1-7 indicators as a target for timeliness in its 2022–2030 Regional Strategy for Health Security and Emergencies (WHO Regional Committee for Africa 2022).

Anticipating and containing complex outbreaks of priority and novel diseases require tracking and measuring metrics through equitable collaborations between the human, animal, environmental, and plant sectors at the local, national, and regional levels. Recognizing that a multisectoral approach is optimal for detecting and mounting a coordinated response, both the 7-1-7 approach and the One Health timeliness metrics framework support joint after-action reviews as an opportunity to review performance and share data among relevant stakeholders. The One Health timeliness metrics framework additionally proposes that, when possible, dates be tracked for predictive alerts of potential outbreaks and preventive responses to early signals.

Combining sustainable use of natural resources and human and animal health expands One Health methods toward strategy analysis using game theory (Bucher et al. 2023). For global public goods with overwhelming benefits outside of isolated countries, financing often requires international cooperation and solidarity, especially for issues that have global externalities, such as climate change or pandemic risk. At the other end of the spectrum, some of the co-benefits generated by a One Health approach are private goods, such as improved on-farm biosecurity that might improve profitability and resilience of livestock operations (refer to the example in figure 3.2).

Figure 3.2 Synoptic View of the Costs and Benefits of Mass Animal Vaccination against Brucellosis in Mongolia

US dollars (million)



Source: Roth et al. 2003.

Note: Cost sharing between public health and animal health makes the intervention extremely cost-effective and efficient.

Investing in Prevention

Part of the attention to One Health involves growing interest in the prevention element of the prevention, detection, response, and recovery spectrum. Calls to action have highlighted possible pathways aimed at reducing risk, such as the elimination of live animal markets. At the same time, these broad-stroke prevention measures create concerns about equity, unintended consequences, and disempowering local stakeholders who need to be part of the design and buy-in for successful uptake. Social inclusion is particularly relevant to these dialogues. For example, Indigenous Peoples make up approximately 5 percent of the population and steward land encompassing 80 percent of the world's biodiversity but are not adequately included and prioritized in decision-making processes (Masaquiza Jerez 2021).

In addition, although not routinely tracked, spending on prevention is widely recognized to result in magnitudes lower costs relative to the response required when diseases are not prevented. Prevention can be highly cost-saving, but the current level of investment is inadequate to produce intended effects. Analysis published in 2022 found that a One Health–based approach to pandemic prevention would cost an estimated US$10.3 billion to US$11.5 billion each year for three core areas of focus: strengthening animal health and veterinary services, improving on-farm biosecurity, and reducing deforestation or forest degradation and improving conservation (World Bank 2022). This cost represents 30 percent of the cost of pandemic preparedness (US$30.1 billion per year) and less than 1 percent of the cost of COVID-19 in 2020, estimated by the Group of Twenty Joint Finance and Health Taskforce. In addition, such investments in prevention have clear potential

co-benefits, among them reducing emissions, addressing AMR, improving animal welfare, and limiting risky contact between animals and people. Improved preparedness ensures that systems are in place to both anticipate and reduce risks, as well as to effectively respond when disease events occur. Investing in enhanced preparedness is recognized as key to resilience.

CHALLENGES TO ONE HEALTH IMPLEMENTATION

In addition to the difficulties of enumerating benefits from prevention, implementation of the One Health approach also has challenges and limitations. The timing of the emergence of One Health internationally meant that it evolved in an emergency and development context, and so has maintained the ethos of development paradigms, including challenges to equitable collaborative governance and power imbalances, as well as restrictions to the scope of stakeholders and actors and methodologies included (Mumford 2023). Engagements have subsequently left out many essential sectors, simply because their representatives weren't at the table when the approach was first developed for emergency response. For example, a long-standing issue involves properly recognizing the role of plants and the environment, and integrating the relevant ministries and departments into planning and activities. This problem is often compounded by underrepresented agencies and ministries being simultaneously underfunded and unable to adjust priorities to health collaborations, especially when budgets are compared to human health and animal agriculture sectors.

The COVID-19 pandemic has highlighted how changes in the environment affect human health. Despite this improved recognition and heightened interest from all sectors, there has been little change in the relative distribution of funds in most countries to allow for equitable multisectoral implementation of the One Health approach. Some signals indicate promise for needed improvements, including specific mention of using the One Health approach in important guidance documents, such as the Pandemic Fund, WHO's Pandemic Treaty, revisions to the International Health Regulations (2005), the US Biden-Harris Administration's bold 100 Days Mission, and numerous statements and convening documents from the Group of Seven and Group of Twenty. Thus, we are in a critical moment for One Health, with a window of opportunity for broad application but with a need to measure and clearly articulate the tangible benefits to improve the health of animals, people, plants, and ecosystems.

Funding for Global Health Security

Before the COVID-19 pandemic, the US government invested in global health primarily through a lens of specific diseases. Examples include the President's Emergency Plan for AIDs Relief, with over US$100 billion invested since 2003 in the global HIV/AIDS response; the President's Malaria Initiative, with over

US$16.4 billion invested since 2005 to combat malaria in the hardest hit nations in Africa; international tuberculosis activities, with over US$45 million invested since 2013 for global tuberculosis control; and the Global Fund to Fight AIDS, Tuberculosis and Malaria, with over US$53 billion contributed since 2013. US federal appropriations have been earmarked to these specific funds to ensure support for the intended efforts. These efforts, of course, contribute to the strengthening of public health systems in general and to improved capacities to combat these diseases, but they do not go far enough to encourage holistic strategies to plan for, prevent, and respond to Disease X. Flexibility in the use of funds under these programs could go a long way in building and supporting health systems that desperately need to be strengthened across diseases. After suffering impediments to implementation and losses in service delivery during the COVID-19 pandemic, many of these programs are ready to get back to previous activities. Their focus, however, should be shifted to strengthening public health systems in general to try to regain both the services lost and improve public health resilience in general.

Although the COVID-19 pandemic heightened awareness of zoonotic disease transmission, by the time investments in response were made, the disease had already become a human-to-human concern. Thus, emergency investments, rightly so, were made to strengthen public health systems for humans only. The fact that the disease-causing virus initially spilled over from animals is often forgotten or ignored when considering how to best prepare for the next emerging health threat of significance, similar to what has happened for HIV. A major concern remains that future funding will continue to focus on human-oriented public health systems only and overlook the strengthening of animal health and food systems, including through the distribution of Global Health Security funds. We cannot continue to repeat this mistake if we are going to be ready to prevent and respond to future spillover events that will cause large-scale epidemics and pandemics without intervention. The evidence for global health security shows that

> One Health approaches appear to be most effective and sustainable in the prevention, preparedness, and early detection and investigation of evolving risks and hazards; the evidence base for their application is strongest in the control of endemic and neglected tropical diseases. For benefits to be maximized and extended, improved One Health operationalization is needed by strengthening multisectoral coordination mechanisms at national, regional, and global levels (Zinsstag et al. 2023).

Ongoing Needs

For most countries that are actively advancing and integrating their public and animal health systems, opportunities to develop in the following areas remain:

- *Capability strengthening.* Knowledge and skill development in study design, study implementation, transdisciplinary collaboration, field sampling, pathogen detection, and data management and analysis, as well as workforce development in all sectors using a One Health approach.

- *Capacity improvements.* Public and veterinary laboratory advancements and establishment of laboratory networks, biobank maintenance, surveillance system innovation, biosafety and biosecurity controls, and multisectoral engagement competencies.
- *Gap assessments* using lessons learned from health projects outside of emergency responses to identify areas for improvement on an ongoing basis. Identified gaps can be used to plan for improvements if an easy mechanism exists to feed data and suggestions into public health planning.
- *Relationship strengthening and partnerships with Indigenous Peoples and community partners* to learn from and incorporate previously underappreciated research, longstanding knowledge, and lived experiences.
- *Networking with global experts* to maintain trusting relationships across geopolitical boundaries and to allow for collaboration during the next emergency.
- *Regional response systems*, composed of neighboring countries with similar environments and risks, for early alert action, regional knowledge-sharing, and support.
- *Strengthening coordination and information sharing within one country* among local, subnational, and national human health and animal health reporting systems.
- *Community engagement* to engender trust with science and health systems, combat misinformation, deliver practical training, and co-develop effective intervention plans.
- *Effective use of One Health platforms* to coordinate and improve systems and to leverage synergistic funding.

Workforce Essentials

Despite the increased recognition and endorsement of the importance of One Health by international organizations and governments in the wake of the COVID-19 pandemic, the One Health workforce remains difficult to characterize because One Health is an approach to complex health problem-solving rather than an occupation. Efforts to characterize the workforce have most often focused on a single sector or discipline, such as human medicine. No accreditation exists for One Health training, such as that for public health, and no centralized registries exist for One Health workers, as are common in dentistry or veterinary medicine.

To begin to fill this gap, a multinational cross-sectional online survey of students, graduates, workers, and employers in One Health identified essential training areas especially valued in the One Health workforce: interpersonal communication, communication with nonscientific audiences, and the ability to work in transdisciplinary teams (Togami et al. 2023). Survey participants deemed the ability to clarify the expectations, roles, and responsibilities in a transdisciplinary team early on in project development; avoid the use of jargon or technical terms when communicating in a multisectoral team; and seeking opportunities to work across disciplines and organizations for collaborative team building important for a One

Health worker. They also noted the importance for trainees of seeking out positions even if not explicitly advertised as One Health, because the One Health approach is essential to most jobs within the relevant sectors. For employers, hiring candidates with an interdisciplinary and collaborative approach was deemed essential, and it was suggested to use the term "One Health" and associated competencies in job descriptions for recruitment.

Training and workforce programs are beginning to fill gaps. The One Health Workforce project—funded by the United States Agency for International Development and implemented by partners in Africa, Asia, and North America—has strengthened the One Health workforce across 17 countries since 2009. In the most recent One Health Workforce–Next Generation project, One Health university networks in Africa and Southeast Asia have strengthened core competencies and workforce capacities through programs at more than 110 universities. In addition, One Health training is no longer limited to formal degree-granting programs at universities. As massive open online courses continue to gain popularity, open-access online modules on employing and operationalizing the One Health approach have become available. For example, OpenWHO, universities in North America and Europe through platforms, such as Coursera and FutureLearn, and One Health Workforce Academies, among others, offer foundational knowledge and evidence-based case studies of One Health through structured online modules.[2]

CONSIDERATIONS FOR OPERATIONALIZED AND EFFECTIVE ONE HEALTH

The world's land and water uses are now completely dominated by people and our preferences for certain plants, terrestrial animals, and aquatic species. Humans have modified the global ecology for our benefit; at the same time, however, we have introduced risks to our own health, as well as to that of the plants, animals, and environment on which we all depend. This major change has resulted in the greater frequency of pandemics and epidemics of people and animals, principally associated with livestock food systems (refer to map 3.1).

One Health is continuing to evolve to address complex challenges, including and beyond infectious diseases, such as the climate crisis and how to feed our growing global population. Many of these complex problems are driven by major modifications of land use, especially through encouragement of cropping and grassland systems that support grain, vegetable, and fruit production for human food, as well as grass and crops to support animals needed for food consumption and for companionship and sport. Consequently, plant health, a previously underrepresented discipline in One Health, is now increasingly recognized as critical in employing the approach. Improving plant health is closely linked to safer foods and greater food availability associated with increased crop yield (Rizzo et al. 2021). In addition, the needs for the One Health approach are becoming more apparent in addressing the complexity of food systems and the problems generated from

their antiquated designs. For example, our systems are generating an obesogenic environment in societies that have reduced need for manual labor and exercise. This powerful combination has led to a rapid rise in obesity and associated major health issues, with crippling impacts on health systems.

Similarly, the inappropriate use of antimicrobials, driven by the presence of infectious diseases in populations, is leading to shifts in resistance of pathogens to known pharmaceuticals and major problems and costs in health care, life expectancy, and potentially food systems. Although One Health has been employed to study AMR, more holistic interventions are needed to prevent the exacerbation of and to mitigate the impact of antimicrobial resistant pathogens, including good antimicrobial stewardship across human, animal, and environmental health (WHO 2019, 2023). Examples of good stewardship include responsible prescribing practices in human medicine, limiting use of antimicrobials in animals for growth promotion, and improving the management of human and animal waste and byproducts from manufacturing to avoid the contamination of water, soil, and other environments with resistant microbes and those that easily incorporate resistance factors (Larsson and Flach 2021; WHO 2023).

In contrast to overdeveloped, extraction-based food systems, Indigenous communities in remote and rural regions often rely in part or whole on subsistence living in which they acquire, prepare, preserve, and consume food via hunting, fishing, and gathering from the lands and waters (Burnette, Clark, and Rodning 2018). Efforts to improve global food systems should employ the Tribal knowledge and Indigenous research that has led to better sustainability in these systems; however, Tribal and Indigenous systems continue to face their own significant challenges. Ending hunger and disease, and improving health, wellness, and resilience based on subsistence in these regions requires the following approaches:

- Affirming and upholding subsistence rights and activities, often limited by historical and contemporary oppression and persecution, or federal and state legislation, policy, and management of land (Burnette and Figley 2017; McKinley 2022)
- Expanding traditional knowledge applications for food safety and surveillance that reduce and eliminate zoonotic illness and disease (Hueffer et al. 2013)
- Offsetting economic marginalization, enabling improved and sustained access and practice of subsistence lifeways not only to survive but also to thrive and promote healthy communities (Burnette, Clark, and Rodning 2018; Reo and Whyte 2011)
- Coordinated efforts with representation from Indigenous traditional knowledge and rights-holders, policy makers, appropriate agencies or organizations (such as health departments, centers for disease control, and research and education institutions), and infrastructure to support ongoing, culturally responsive training, monitoring, diagnostics, and preventive measures (Hueffer et al. 2013).

As noted earlier, negative externalities of public health are being increasingly recognized, and the associated impacts of the land and water use changes of food production are also now well documented (Rushton et al. 2021). Only relatively recently, however, have methods to capture these impacts been developed and applied in a system called the True Cost Accounting for Food (Gemmill-Herren, Baker, and Daniels 2021). This approach begins to address what needs to be measured in order to understand more carefully the impact of human activity on the ecological system in which we live and work and on which we are completely dependent. Thus, limiting the negatives of emerging threats, endemic diseases, and environmental change—at the same time that we optimize food systems to provide affordable, acceptable, and high-quality foods—requires advancing the One Health approach to improve metrics in all applications, as well as to optimize evaluation and decision-making processes.

One promising development is the push for greater focus on the health of the planet, rather than simply measuring outcomes with regard to human health and associated costs or savings. The holistic and interdisciplinary approach promoted by One Health links nicely with this more recent planetary health movement: "solutions-oriented, transdisciplinary field and social movement focused on analyzing and addressing the impacts of human disruptions to Earth's natural systems on human health and all life on Earth."[3] One Health and planetary health have both gained popularity and been recognized by health practitioners as essential in recent years. These concepts can help highlight the complexity of systems involved in the world's problems and, therefore, can be used to more thoughtfully address the adverse outcomes associated with the drivers of global health challenges, such as the changing climate, population growth, health disparities, fossil fuel consumption, and changes in land use.

The Importance of Addressing Complexity When Using the One Health Approach

Both biological systems—those for which One Health approaches have been applied—and the larger socioecological systems in which they sit are considered complex adaptive systems. In Systems Science, which is its own scientific field, the interconnections and relationships between the elements or variables, not the variables themselves, are of the most interest. The terms "systems" and "complexity" are used inconsistently in One Health policy and technical discourse. When used to refer to One Health assessment or analysis, "systems" analysis tends to refer to mechanistic modeling methods used to understand causal relationships among variables in the system, such as for prediction.

In contrast to mechanistic systems, "complex" systems—for example animal bodies and the global internet—are by definition nonlinear (although some of the relationships inside them may be linear) and are unpredictable because of certain characteristics, such as adaptation, emergence, self-organization, and tipping points. Using both qualitative and quantitative Systems Science methodologies can be useful for understanding potentially unexpected components and

relationships in the broad system and exploring the sometimes-distant impacts of manipulating them.

Given the complex and converging global challenges which One Health is now poised to help solve, there is a pressing need to expand the approach in three dimensions, namely scope, methodologies (or approach), and worldview (Mumford et al. 2023). An evolution in *scope* refers to the plurality of stakeholders and the expertise, experience, knowledge, and perspectives they bring, and, in particular, the need to expand effective and engaged partnerships to include affected communities, including Indigenous Peoples and voices from marginalized populations. An evolution in *methodologies* means inclusion of new or existing but underutilized methodologies and approaches to address some of the challenges in collaborative governance, inclusion of knowledge, and management of complexity inherent in One Health activities, and for which current, mainstream Western scientific methodologies are insufficient. An evolution in *worldview* means authentic consideration and respect for diverse and potentially conflicting worldviews in the planning and implementation of activities (Mumford 2023).

The Role of Culturally Responsive Education in One Health

A paradigm shift to the inclusion of Indigenous knowledge and methodologies in predominantly Western education systems is well under way, but addressing power relations that view Indigenous knowledge as a tool in existing Western scientific and bureaucratic processes will require work (Barnhardt and Kawagley 1999; Nadasdy 1999). The 2030 Agenda for Sustainable Development calls for the empowerment of Indigenous Peoples, inclusive and equitable education for all, and engagement of Indigenous Peoples in implementing the Agenda, including "equal access to all levels of education and vocational training."[4] Comparatively, however, very few mainstream or Western education frameworks and programs include Indigenous Peoples and cultural competency in core curricula, required courses, or classroom settings (Barnhardt and Kawagley 1999).[5] In light of the ongoing and disproportionate effects of climate change on Indigenous and other marginalized communities, local education and capacity strengthening based on community needs and priorities is crucial to strengthening the next generation of human-animal-plant-environment health practitioners and stewards. Increasing the diversity of perspectives within One Health curriculum and associated degree programs is an area that needs to be improved to combat systemic racism, barriers, and health inequities among underrepresented and underserved groups.

Many Indigenous Peoples consider the land a resource that behaves as a living being and provides the life support system for animals and humans to thrive (Montesanti and Thurston 2016). This connection to the land emphasizes how the health of the land is central to Indigenous communities' health and wellness (Montesanti and Thurston 2016). Indigenous views of health take a holistic approach based on interconnected social and ecological systems (Hueffer et al. 2019). Integrating Indigenous knowledge means moving away from the current westernized model of

health to include knowledge that is fundamentally relational—linked to the land, language, and the intergenerational transmission of songs, ceremonies, protocols, and ways of life (Greenwood and Lindsay 2019).

As a term, "One Health" can be seen as yet another colonial term that does not fully reflect Indigenous Peoples' worldviews. Indigenous worldviews and knowledge about holistic health and well-being preceded the evolving concept of One Health in veterinary and human medicine. Within the One Health framing, human health is usually listed first, and this order provides the passive presumption that the preservation of human health is the primary driver of actions (OHHLEP et al. 2022).[6] This prioritization runs counter to the worldview of humans as stewards of the natural world, protecting the health of our ecosystems and waterways, ensuring the continued care of animals and plants, and living in balance rather than over harvesting. Only through reordering our priorities may we start to bring One Health into alignment with traditional understandings of balance.

Indigenous early learning frameworks (for example, Canada's Indigenous Early Learning and Child Care Framework, established in 2018) founded on Indigenous climate action and land-based education, coupled with mainstream One Health principles, can improve science literacy, dissemination, and communication and ultimately enhance resiliency, wellness, and health outcomes. One Health programs grounded in cultural identity and local languages can support community mechanisms for experiential and intergenerational learning. Culture-based and co-learning among elders and K–12 youth can initiate knowledge exchanges across various spatiotemporal dimensions, including scalability in individual and community well-being.

Co-production of Knowledge

"Through scientists entering into dialogue and mutual learning with societal stakeholders, science becomes part of societal processes, contributing explicit and negotiable values and norms in society and science, and attributing meaning to knowledge for societal problem-solving," a process known as transdisciplinarity (Hirsch Hadorn et al. 2008, 3). It is a pillar of One Health approaches, with scientists and nonacademic actors from several disciplines, including authorities and communities, collaborating in the co-production of academic and practical knowledge for the solving of societal problems (Schelling et al. 2008).

Tapping the Power of Data Science

Similarly, effective and judicious use of artificial intelligence (AI) and its subset, machine learning (ML) can greatly improve One Health research and interventions. Both AI and ML are being used with increasing frequency in domains across science. Accessing all the necessary data and ensuring the capacity to integrate them to address global challenges will require that One Health approaches include computational scientists along with relevant subject matter experts. The recent

advances in generative AI, such as ChatGPT, have transformed discourse on the future of AI-driven applications in modern human life, but they come with ethical, legal, environmental, and social concerns (Harrer 2023).

Contributions of AI/ML models to human, animal, and environmental health span a variety of applications:

- *Disease surveillance and control***.** ML techniques have been used with different data types (for example, geospatial, remote sensing textual, genomic, and network data) to predict transmission patterns and outbreaks of pathogens and diseases, such as Zika virus (Jiang et al. 2018), dengue (Scavuzzo et al. 2018), and malaria (Haddawy et al. 2018); to forecast transmission of SARS-CoV-2 (Ward et al. 2022); to determine relevant disease outbreak information (Freifeld et al. 2008); and to predict host-virus interactions to identify potentially zoonotic viruses (Brownstein et al. 2023; Pandit et al. 2022; Poisot et al. 2023).
- *Human health policy and planning.* Algorithms such as XGBoost have been used to identify patients who potentially have long COVID-19 and warrant care at specialty clinics (Pfaff et al. 2022). ML models have also been used to predict length of stay among health care workers in underserved communities in South Africa, providing a means for planning and optimizing public health care recruitment (Moyo et al. 2018).
- *Food safety.* AI-assisted detection of potential bacterial contamination in food products opens up the possibilities of a framework for automated bacterial detection for earlier detection and prevention of foodborne illnesses and outbreaks (Ma et al. 2022).
- *Food security and agriculture*. Deep learning models have been used for image-based plant disease detection, opening up the potential for crop disease diagnosis on a global scale (Mohanty, Hughes, and Salathé 2016). Similarly, many other applications of ML in agriculture include use for weed detection and soil management (Coopersmith et al. 2014; Liakos et al. 2018; Pantazi et al. 2017).
- *Wildlife health and conservation*. Automation of animal identification in data sets of upward of 3 million images has been demonstrated with deep learning algorithms, with an accuracy similar to crowdsourced teams of human volunteers. This method has the potential to reduce cost and to free up human labor to solve more complex questions on animal behavior, ecosystem dynamics, and wildlife conservation (Norouzzadeh et al. 2018).
- *Climate*. Cowls et al. (2021) discuss the many roles of AI in combatting climate change, including for forecasting events associated with climate change, such as prediction of wildlife probabilities (Jaafari et al. 2019). In addition, ML and natural language processing methods have been used to systematically map global research on climate and health (Berrang-Ford et al. 2021).

Big data and AI will drastically alter how worldwide monitoring systems operate to detect pathogens and disease transmission (Osterhaus et al. 2020). Along with the increased reliance and proliferation of AI models come associated challenges that range from ethics underpinning AI models and the data they use to transparency,

fairness, and the "possible exacerbation of social and ethical challenges already associated with AI" (Cowls et al. 2021; refer also to Harrer 2023).

Digitization of data raises important concerns over the protection of Indigenous knowledge and intellectual property rights, a longstanding issue across Indigenous communities. Presently, however, no international accountability and transparency measures or processes exist to assess whether global One Health research meets Indigenous standards and principles of protection (Carroll et al. 2021). Consequently, open data processes must follow Indigenous sovereignty and assertions outlined by both Tribal communities and individual rights. New applications of One Health could serve as a catalyst to assess multisectoral data challenges, improve intersectoral collaboration, and develop or improve Indigenous data protection metrics for collective and individual rights.

One Health programs, initiatives, and operations can protect Indigenous knowledge and cultural integrity by establishing a shared Indigenous community-based process for review and authorization of research, including explicit recognition, acknowledgment, and adequate compensation to Indigenous partners, knowledge holders, and culture-bearers. For example, the Alaska Native Knowledge Network provides guidelines for "documentation, representation, and utilization of traditional cultural knowledge as they relate to the role of various participants, including Elders, authors, curriculum developers, classroom teachers, publishers and researchers" (ANKN 2022, 3). One Health guidelines for incorporation of Indigenous knowledge systems in health mandates; diversity, equity, and inclusivity efforts; and teaching within classrooms can prevent misuse and appropriation of knowledge.

In consideration of the ethical concerns regarding the use of AI for health, WHO (2021) has put forth five principles to support the adoption of ethical approaches by governments and interested parties:

1. *Protecting human autonomy*. Use of AI should not undermine human autonomy and should ensure protection of privacy and confidentiality. Valid informed consent should be obtained through appropriate legal frameworks for data protection.
2. *Promoting human well-being and safety and the public interest*. Use of AI technologies should not cause harm, either mental or physical, to people.
3. *Ensuring transparency, explainability, and intelligibility*. AI technologies should be transparent in their design, intelligible or understandable to the concerned parties (including users), and appropriately explainable to those to whom they are explained.
4. *Fostering responsibility and accountability*. AI use should be supervised by humans, and in case of problems associated with AI technology, accountability should be ensured via appropriate mechanisms.
5. *Ensuring inclusiveness and equity*. AI for health should be designed to "encourage the widest possible appropriate, equitable use and access, irrespective of age, sex,

gender, income, race, ethnicity, sexual orientation, ability or other characteristics protected under human rights codes" (WHO 2021, xiii). In addition, AI technologies should not be biased, especially against already marginalized groups.

Keeping the principles for the ethical use of AI in mind, it is imperative that governments, academic institutions, and organizations also fund research to support the development of software tools in parallel with other academic and research outputs (Jombart 2021). As seen during the COVID-19 pandemic, outbreak analytics and disease modeling results inform the response to infectious disease outbreaks (Kucharski, Funk, and Eggo 2020). Ensuring the impact and sustainability of these tools will require prioritizing and supporting the development of high-quality scientific software, including but not limited to that incorporating AI approaches, especially for genomics.

Financing Mechanisms

Although ministries of health, agriculture and livestock, and the environment are recognized as core to One Health implementation at the country level, ministries of finance play perhaps the most critical function through their allocation and supervision of national budgets. Even when political will for One Health is high, the absence of domestic or donor financing hinders implementation of activities and can lead to unsustainable programs. Lack of equity in financing—including donor-driven projects that target specific issues but may not always address local priorities—has resulted in uneven effort or focus from the concentration of available resources.

From global to local levels, enabling coordination among sectors (ministries, departments, and their stakeholders) in and between emergencies requires simplifying budget and administrative procedures. Maintaining collaborations and long-term commitments presents a critical challenge. Despite the devastating multigenerational socioeconomic impacts of the COVID-19 pandemic, the attention of global leaders is already being diverted to other issues, with a demonstrable reversion of ministry and agency activities to prepandemic siloed approaches. Improved coordination and cross-sectoral investments must continue and should be paired with investments in sector-specific activities and programs that support efficiency and effectiveness, including as part of existing and future plans and priorities. Aside from epidemiological plausibility, a key consideration for interventions must be feasibility, shaped in part by acceptability to stakeholders. Factors including preference, values, and priorities can play a role in willingness to accept (and, in some cases, pay for) interventions or other strategies. Resourcing for subnational implementation is also crucial, including enabling action at local levels. The local workforce, such as community human and animal health workers and eco-guards, should be equipped and incentivized to work together. The role of veterinary services can hardly be overemphasized, yet they are most often underresourced.

Although some financing gaps are likely to require new or additional resources, existing resources can also be leveraged or repurposed under a One Health approach, for example to develop synergies in programs for human, animal, plant, and environmental health systems. The improvements of laboratories, information systems, and immunization schedules offer potential examples.

CONCLUSIONS

The message is clear: the key to modern health problem-solving is to foster effective partnerships and collaborations across sectors at local, national, regional, and global levels and holistic identification of equitable solutions to complex global problems. Those problems include local land use changes that affect living systems globally, the climate crisis, food system instability, and challenges linked to infectious diseases. Humanity can no longer ignore the suffering of the world's poor and marginalized peoples, the silencing of Indigenous Peoples' voices, nor can we continue our Western mainstream culture of inequities, colonialism, and oppression that contributes to health and social inequities. We cannot continue to burn fossil fuels and forests to support a lifestyle of excess that is rapidly becoming unsustainable. And we cannot continue to address individual and global health using linear, reductionist approaches that fail to consider or address the complexity of the social and ecological systems that influence it (Mumford 2023; Mumford et al. 2023).

Despite the growing evidence base for the benefits of One Health and the recognized need for greater coordination to maximize resources, uptake is still limited (Zinsstag et al. 2023). The typical siloed ways of working result in budgets that are not readily equipped to direct resources where needed, across sectors. Departments and ministries have long histories of scope and operational arrangements that often end up creating vertical programs with limited horizontal, agile capacities, especially when roles and responsibilities are fragmented across multiple agencies, leaving gaps and, in some cases, overlaps. Consequently, the typical starting point is "What can I do?" versus "What needs to be done?" (Berthe et al. 2018). These issues of mandates, capacity, and poor coordination affect ability to deliver on commitments. Equipping key players to act and addressing gaps will require alignment across agencies, reinforced by budget mechanisms (Berthe et al. 2018).

In 2022, the Quadripartite launched a One Health Joint Plan of Action with six action tracks: (1) One Health capacities for health systems; (2) emerging and reemerging zoonotic epidemics; (3) endemic zoonotic, neglected tropical, and vector-borne diseases; (4) food safety risks; (5) antimicrobial resistance; and (6) integrating the environment into One Health (FAO et al. 2022). The plan provides concrete activities and metrics from which to build, with country and regional implementation envisioned, as well as translation of the plan to the local context. To support a coherent approach from agency engagement at the country level, Resident Coordinators that oversee United Nations operations at the country level are being engaged. This engagement and the role of National One Health

Coordination Platforms, working closely with local champions, could potentially increase the impact of One Health approaches across the sustainable development agenda. These plans could be expanded to include activities that incorporate Indigenous Peoples and their knowledge into all engagements, and increasing focus on the inter-related issues of land use change, biodiversity loss, unsustainable food systems (beyond food safety), and the climate crisis.

NOTES

1. Refer also to the US Centers for Disease Control and Prevention's "One Health" web page, https://www.cdc.gov/one-health/?CDC_AAref_Val=https://www.cdc.gov/onehealth/global-activities/prioritization.html.
2. For more on One Health Workforce Academies, refer to the organization's home page, https://onehealthworkforceacademies.org; refer also to World Health Organization, "Your New OpenWHO.org," https://openwho.org/.
3. Planetary Health Alliance, "Planetary Health," https://www.planetaryhealthalliance.org/planetary-health (accessed April 7, 2023).
4. United Nations, Department of Economic and Social Affairs, Social Inclusion, "2030 Agenda and Indigenous Peoples," https://www.un.org/development/desa/indigenouspeoples/focus-areas/post-2015-agenda/the-sustainable-development-goals-sdgs-and-indigenous.html.
5. For examples of One Health degree pathways across institutions or institutes, refer to Frankson et al. (2016), Hillier et al. (2021), Riley et al. (2021), and Togami et al. (2018).
6. Refer also to the US Centers for Disease Control and Prevention's "One Health Zoonotic Disease Prioritization (OHZDP)" web page, https://www.cdc.gov/one-health/php/prioritization/index.html.

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