Place Figure F.1 here: Women practicing One Health in a peri-urban village near Dhaka, Bangladesh. The women are drawing maps and timelines of disease events and related practices in the village, a method used by the Food and Agriculture Organization of the United Nations to encourage ownership of One Health by local villagers. Photo by author, February 19, 2019.

Foreword

The Lure of One Health

Steve Hinchliffe

A lure is something that entices, tempts, or appeals. It's also a trap, a decoy.

Introduction

In order to survey wild bird populations for avian influenza, conservation managers and volunteers use lures to round up waterfowl on various wetlands in the UK. The aim is to estimate the environmental load of avian influenza, sending samples back to the government's veterinary laboratories. If all goes well, officials within the relevant ministry will then be able to understand the threat posed to poultry farming, as well as making some sense of the risk, by no means improbable, that the avian influenza virus would evolve or adapt into a pathogen of pandemic potential.[1]

The lure of One Health is of course more than placing food on a platform at a wildfowl reserve at the break of dawn. It is the easily appreciated sense that people, plants, animals, and their environments, share health outcomes. It is the positive sum game, wherein gains in environmental and nonhuman animal health benefit humans, and vice versa. It's a collective approach to inextricably shared fortunes; *one for all and all for one*. It is an ecological extension to the ancient Roman dictum "*Salus populi suprema lex esto*"—the health of the people should be the supreme law—only translating people or population as a more than human matter.[2]

The trap of One Health is also more substantial than the temporary discomfort experienced by wild birds prior to being released back onto the wetland. Indeed, One Health

might obscure some important questions, or even imply that something can be delivered smoothly and in an uncontentious manner, when in fact there are bound to be uncomfortable trade-offs and compromises. The calculus may be more complex than the positive sum version implies. By bundling everything and everyone together, are we missing something, skating over questions that still need to be asked regarding how to approach questions of more than human life and health?

I will start this Foreword by focusing on an emblematic case for One Health, demonstrating its attraction and utility. In the process and in what follows, I will open up some less clear-cut issues. I will outline some of the conditions for One Health, and some of the matters that may not quite fit or that remain part of a more uncomfortable calculus and politics of health. In doing this, I hope to set up some resources for reading the chapters in this book. The question to take to this and the pieces that follow might be, what is gained and what might be missed when we adopt the One Health signature?

Definitively One Health: Rabies

Rabies is a viral disease that can be transmitted to people by a range of mammals, notably canids (dogs, foxes) but also bats and rodents.[3] The infection, following a bite from an infected animal, almost always a dog in those countries without rabies controls, can cause inflammation of the brain and, if untreated, will be fatal. Treatment relies on rapid diagnosis (which can be difficult as early symptoms are often unspecific) and timely post-exposure prophylaxis (PEP). PEP involves multiple doses of immunoglobulin and vaccine, is expensive, and often impractical in low resource settings and in remote locations.[4] As a result, infection prevention remains the most effective form of disease management. Measures include managing dog populations through culls and neutering programmes, though this is rarely as effective as it may sound.[5] The reproduction rate (R0) for rabies is largely independent of canine population density, meaning that population reduction may

have little effect on disease risk. Culling may also impact negatively on vaccination programmes as it tends to remove the most easily accessible members of a population. Around 70 percent of dogs within a given population need to be vaccinated in order to disrupt transmission cycles and eliminate the disease in dogs and other mammalian hosts.[6] Vaccines have been available for well over a century, and in many countries with transmission risks, vaccination of companion animals is mandatory. Outside of these areas of successful disease prevention, and particularly in sub-Saharan Africa and parts of Asia, alarming numbers of human cases and associated suffering are almost all associated with transmission from dog bites. In these settings, vaccination programmes can generate huge benefits to human and animal health.

Improving canine health through vaccination reduces the health burden on people, relieves the pressure on under-resourced health care systems, and removes a key reservoir of infection from the environment. It is clearly a win-win situation, a paradigmatic One Health venture. Just as characteristically for One Health cases, there are also potential gains that relate to the roll out of such a program. These include, first, the need for and benefits of working across established disciplinary and health provider boundaries. Second, there is utility in developing community engagement and participation in the delivery of collective health gains. And third, there is the need to secure and develop innovative forms of financial support necessary to initiate and sustain a One Health programme. I will take each of these in turn.

Cooperation between human, animal, and environmental health professions is a key element of any One Health venture. Sharing expertise on a disease, its aetiology, and transmission mechanisms, pooling experience concerning biomedical and other health-related interventions, and devising innovative ways of working across institutional landscapes are key areas for collaboration. Nevertheless, these forms of co-working are often more difficult

than they might be seen. As others have noted, barriers exist in part because of the evolution of biomedical sciences, and in particular the divergence of medical, veterinary, and environmental sciences in the nineteenth century.[7] Just as significantly, medical and veterinary services have tended to develop quite different institutional practices, with unique mixes of state-based and or private forms of service delivery and cost allocation. As a result, there tend to be distinct resource allocations, budgeting practices, sector specific norms in terms of service delivery, variations in terms of the designation of public and private goods, and distinctions in terms of payment vehicles and forms of cost recovery. As One Health programmes are cross-departmental or inter-ministerial in complexion, the result is that numerous services, products, and health care practices need to be aligned. This is especially difficult when the costs of intervention fall on one department or sector while the benefits accrue elsewhere. As Cleaveland et al. explain in relation to rabies control in sub-Saharan Africa:

> It is the human health sector that derives the public health and economic benefits from canine rabies control—the reduction or elimination of human rabies deaths, and reduced need for costly PEP for people bitten by suspected rabid animals. However, it is the veterinary services that generally incur the costs for canine rabies control, but derive few economic benefits, as domestic dogs are not an economically valuable species. Without a sharing of costs and benefits across sectors, there may be little incentive for veterinary services in low-income countries to prioritise investments for rabies control.[8]

The distribution of costs and benefits clearly depends on the specific disease system, host species, transmission pathways and so on. For example, vaccination of livestock for a zoonotic disease may result in improved productivity and lower mortality, benefitting farmers, reducing pressure on veterinary services, providing gains for the food production

sector, or the relevant ministry for livestock or food. In such cases, it may be reasonable and practical for the veterinary service, farmers, the relevant sector or ministry to contribute to an intervention which provides direct benefits to those sectors. For companion animals, wildlife, and other environmental health interventions, and, indeed, when the agricultural sector is characterized by large numbers of small holders, cost recovery is likely to be more complicated, especially in lower income settings. Where animal ownership is uncertain (where there are high proportions of street or free-roaming dogs) and/or where keepers do not have the resources to pay for animal medicine, there are real barriers to reaching the required levels of compliance to make a programme effective. In these circumstances, alternative means of delivering cross-sectoral health gains need to be developed.

This cross-sectoral issue and the need for a joined-up approach to health service delivery extends to a transdisciplinary, participatory, or engaged approach to public health. One Health initiatives, in other words, may be more successful when a broad coalition takes shared ownership and can recognize a collective benefit. Some of this is a matter of good communication, while in other cases there are more active attempts at coproduction of health initiatives and outcomes.[9] For the rabies case, in resource scarce environments with stretched veterinary services, engagement may help the vaccination process—training local auxiliaries or para-vets to vaccinate dogs as well as generating community ownership of a programme can help to increase vaccination rates. Similarly, once the programme has started, health service workers and communities need to be confident that there is indeed a diminished risk of infection. Community engagement with the programme, and its results, can help to alter health seeking practices and relieve pressure on health systems. People need to be confident that the risk of infection with rabies have decreased substantially in order to refrain from administering or demanding expensive PEP. In turn, this requires ongoing investment in veterinary surveillance and diagnostic capacity to maintain robust disease transmission risk

estimates and develop appropriate evidence for vaccination effectiveness. Sharing scarce laboratory facilities in ways that benefit both human and animal health care sectors will aid this joined up approach to One Health.[5]

There are good reasons to suppose that some of this community engagement and ownership of a One Health issue can increase in the future—better access to stable vaccines, rapid or point of care diagnostic tests, widely available mobile telephony and so on are all potential contributors to the vision of a One Health and community-based solution to a zoonotic disease. As Cleaveland and colleagues note: "community-directed interventions may be feasible, and deliver more cost-effective and sustainable approaches to rabies control in Africa than centrally coordinated strategies implemented by the veterinary services alone."[10]

While community engagement may help to improve efficacy and reduce the burden on poorly resourced and stretched veterinary and health services, financial support remains crucial to One Health initiatives. One-off or catalytic funding may be useful in terms of purchasing vaccines and training dog handlers, but subsequent vaccinations, antibody surveillance, and maintenance of disease control programmes, require ongoing funding. As with other, solution-based and cross-domain forms of development, One Health increasingly tends to be linked to new kinds of pharmaceutical, health care, and development financing.[11] In the rabies case, Cleaveland et al. suggest that some of the issues with supporting a programme of rabies control might be solved by development impact bonds (DIBs). Given the intrinsic sectoral barriers to One Health initiatives, the uneven distribution of costs and benefits, and the delay to realising downstream benefits, impact bonds seem custom made for One Health initiatives.

These packages are part of the globalization and financialization of health and development.[12] Like catastrophe and vaccine bonds, they allow for the generation and release of larger amounts of finance than would normally be made available from state lenders or

official development assistance.[13] As Mawdsley notes,[14] conventional catalytic funds are effectively used to "leverage private sector investment" transforming "aid" into "growth" oriented financing. While catastrophe and vaccine bonds allow investors to hedge their investment by covering a wide geographical area, DIBs are designed to generate returns on investments once a pre-determined and externally verified set of objectives have been reached. The host state effectively sells an option in its future health or development status, with capital investments earning returns for the investors based on the delivery of those health and development gains. The resulting bonds are fungible and tradable assets, making them economically efficient in the terms set by international financial markets. In effect, they attract the levels of investment that investors regard as appropriate to the risks and time periods of return. They also benefit by being under-written by state or philanthropic aid donations, state lenders or national and international banks, and allow investors to securitize a bundle of risks and investments.

Despite the obvious attraction of novel financing arrangements to One Health type issues, questions remain. First, there is little or no transparency around some of these packages, with finance "leveraged behind closed doors."[15] Second, financialization involves turning health into a market opportunity, arguably altering the conventional humanitarian and security-based regimes of global health.[16] As Mawdsley captures it, this is a "re-configuration of parts of the developing world as the risky frontiers of profitable investment […] Converting the 'mundane' into investable objects and tradeable commodities."[17] Third, marketisation of health investments will inevitably distort resource allocations. Investment decisions based on risk and returns may mean that geographical regions or issues where there is greater uncertainty in terms of science and outcomes, or where access to political capital and resources are already in short supply, continue to be overlooked. Riskier investments may reside in those very areas where there is already social instability but where the need for

health investments is nevertheless greatest. It may be that the most disadvantaged areas, or those in greatest need, the most dangerous in terms of health threats, and the least tractable in terms of solutions, are the least attractive in terms of future funding of One Health programmes.

For Cleaveland and colleagues, the rabies case is definitive: "One Health principles characterise all successful rabies efforts: effective intersectoral partnerships and communication; high levels of community ownership and participation; and strong political support at the local and national levels."[18] To this list of principles, we might add "the international" and a financialized "global" market for development. The requirement to secure new forms of financial support for One Health in lower income countries, an endeavour that is difficult to operationalize on account of cross-sectoral cost and benefit streams, occurs within a competitive funding environment (with investments from China and India as well as old world financial centers). The point of note is that this form of activity is increasingly operating beyond conventional state-based coordination and oversight, involving the release as well as servicing of private finance and capital.

At this juncture, we can list some of the characteristics that mark the One Health paradigm:

- Clear benefits to both human and nonhuman animals, as well as environments
- An identified need to work around existing service delivery and funding models (especially when costs and benefits fall unequally between existing sectors)
- Increased public and community engagement as an opportunity for improved health practices, skills development and as a means to overcome health care resource scarcity
- An exploration of new forms of finance and calculus to generate necessary funds and overcome previously circumscribed budgets and inflexible cost recovery programmes

This is the lure of One Health, and while I have my reservations (particularly around the issue of financializaton), it is an attractive and, in many senses, self-evident case. In what follows, I'd like to briefly touch on some other disease situations.[19] The point is not to undermine the importance of One Health; it is to augment this list with some potential traps that we may, if we are not careful, fall into.

Indefinitely One Health: Guinea Worm Disease (GWD) in Chad

Guinea worm disease (GWD) is a parasitic disease caused by the nematode *Dracunculus medinensis* (the disease is also termed dracunculiasis), with a water-based disease cycle involving larvae passing from open wounds in infected hosts into watercourses. The released larvae are transmitted to new hosts orally via intermediate water fleas, of the copepod family, through consumption of water or via fish and amphibians acting as transport hosts—as depicted in Figure F.2. There are no vaccines or treatments and the results of the disease can be debilitating and may permanently affect the limbs of those infected. Disease management involves water treatment and community engagement, both of which are important measures in interrupting and preventing transmission.

In the mid-1980s, there were around 3.5 million cases of GWD a year. In recent years, and largely as the result of a coordinated global campaign, the number of cases has been around 20-30 per annum. The phenomenal success marked a major achievement of the Carter Center (founded by US President Jimmy Carter), who lead the Guinea Worm Eradication Program (GWEP) building local, national, and international partnerships and coordinating numerous donors. GWD was all set to become the first human disease to be globally eradicated since smallpox in 1980.[20] The effort to do so was based on well-informed assumptions that eradication was biologically feasible, clinically verifiable and the programme would produce numerous additional benefits in terms of improving sanitation as

well as providing public health gains and health care training opportunities. Eradication within a state or region required verification and certification, and was closely managed by international health institutions. The World Health Assembly definition of successful interruption of transmission and elimination of GWD stipulated that "there have been no reports of GWD for three or more years."[21]

Place Figure F.2 here: Life cycle and transmission pathways of *Dracunculus medinensis*. Source: CDC, public domain. This use does not constitute an endorsement by the U.S. Government, Department of Health and Human Services, or Centers for Disease Control and Prevention.

Dracunculiasis was, in several respects, a straightforward public health issue, its eradication conforming to so-called first wave of public health interventions: improving sanitation and interrupting transmission. But the issue has recently taken a turn to become a One Health matter. In the mid-2010s, infections were reported in dogs in Chad and in several other states in Africa. The canine parasites were genetically identical to those in humans, indicating that the disease had become or should now be recognized as a zoonosis (an infectious disease that conventionally speaking has jumped from nonhuman animals to humans, though in this and many other cases, the direction of travel has been reversed).[22] Canine hosts, it was supposed, were now playing a part in maintaining a reservoir of this disease.[23]

In terms of resulting actions, there are parallels to the rabies case. Targeting water treatment programmes in areas close to dog populations and community engagement with disease prevention were advised. The latter included education programmes on transmission, discouraging the feeding of dogs with fish catch remains, rewarding those who reported canine cases and preventing infected dogs from visiting water courses—a controversial practice involving tethering of dogs.[24] But a new issue started to arise in terms of verification and certification of eradication. Once the disease became zoonotic, the logic of disease certification started to look less secure.

In human disease systems, verification and certification may be relatively straightforward, especially in easily diagnosed diseases like GWD, with clinical observation, case reporting, and centralized records generating a disease incidence picture.[25] However, once a pathogen is in nonhuman hosts with wide spatial ranges[26] and the potential for further spill back into wildlife, then the calculative environment may alter. If human health, and the logic of eradication, deals in absolute numbers (case reports), animal health tends to follow a scientific logic that is more probabilistic. As animals do not take themselves to a clinic, and as dog ownership may be unclear, there is likely to be under-reporting of disease. In this case, establishing likely case numbers or environmental pressure is based on developing a robust diagnostic test, sampling a population, and estimating incidence. While field or pond-side tests exist,[27] the Popperian point here is that surveillance for eradication becomes embroiled in a new logic, as we move from clinical cases and numbers to statistical estimates, likelihoods and null hypotheses.

This is robust knowledge, but it is important to note that the logic has shifted from definitive absence of a condition to diminishing risks of infection. The issue is partly epistemological, marking differences between clinical medicine, population medicine, and ecological sciences. But it is also more sweeping than a simple alteration of survey methods. The shift to disease ecology—or the relational science of hosts, environments, and pathogens[28]—is marked by an alteration in logic that unsettles the rationales of eradication or disease-free schema. There is no longer a finite end or vanishing point. Time, in this probabilistic landscape, is now in-finite. The implication is that One Health can start to open up some important questions concerning the "ends" of health interventions, their rationale, and their measurement.

Definitively More-than-One Health: Ponds, Prawns, and Antimicrobial Resistance

This logical conundrum opens up health as a conditional, rather than absolute, end point. And it may contain a crucial lesson if we are to make good on the promise or the lure of One Health. I can illustrate by taking the issue of disease management in relation to the threats posed by, and the solutions offered to, the risks of drug resistant microbes, and specifically antimicrobial resistance (AMR). AMR is becoming one of the leading causes of mortality globally, particularly in parts of Africa and Asia,[29] and has been described as a quintessential One Health issue.[30] Human, animal, and environmental health are all implicated in the use of antimicrobial compounds, in the emergence of resistant organisms, their persistence, and transmission. Like other One Health issues, there is a clear need to develop inter- and trans-disciplinary working as well as cross-sectoral collaboration in order to meet the complex challenges of managing disease risks, altering health seeking practices and reducing transmission of resistant microbes. Yet, as an esteemed clinical and scientific authorship suggest (though notably one without social science representation), a major gap is the appreciation of the socioeconomic drivers of both disease and health-seeking practices. "One Health science seems to fall short when it comes to understanding the economic forces behind many emerging infectious diseases; there is a further gap to be bridged between the biomedical, environmental, and animal sciences, and the social sciences."[31]

The point can be underlined with case studies of disease management in lower income countries. For example, in recent decades, a rapid expansion of inland aquaculture has produced large gains in access to dietary proteins and revenue, especially in Asia.[32] Most production is undertaken by a "missing or squeezed middle" of commercial producers who "enjoy none of the benefits of investments in biosecurity or pathogen control characteristic of intensive systems nor, the low input/low risk/low output typical of extensive systems."[33] These producers are adopting practices such as commercial feed use, water, and livestock

treatments, including antimicrobial uses, but are loosely tied to value chains, subject to little or no veterinary oversight and are weakly regulated by buyers and/or state-based organizations. Disease is a persistent threat—constituting an estimated US$6 billion loss per annum in the global industry.[34] One means of reducing disease burden is to improve the quality and sources of seed stock to farmers. This may involve funding hatcheries to produce specified pathogen free and or certified or tested stock. In Bangladesh, for example, farmers used to pay collectors of wild fry and larvae to stock their ponds—a practice that not only led to environmental damage within fragile mangrove wetlands but also recycled disease between the riverine environment and the ponds. The disease burden was particularly high, with farmers reporting frequent disease problems in their ponds.[35] Farm supply shops in Bangladesh were increasingly operating concessions and pressured by wholesalers and commercial salespeople to increase sales of treatments to farmers (who have little access to other expert advice). Given the disease burden and the availability of over the counter antimicrobials, even small amounts of which are thought to be potentially significant in aqueous environments,[36] there would seem to be a strong case for a One Health intervention.

In this situation, it may seem a straightforward statement to suggest that certified disease-free hatchery seedlings would reduce disease burden, interrupt transmission from farms to rivers and its recycling to livestock via wild seed, and lower the impact on mangrove habitat. The reduction in disease would in turn reduce the likelihood that farmers would have use for medicines and treatments that are potentially damaging to environmental and human health. From a One Health perspective, this looks like a win-win situation. Finance for the hatcheries and relevant NGOs was available in the form of international loans and grants, and hatchery owners secured tax concessions that allowed the technical innovations to proceed.

Yet, at the pond side, farmers initially saw little change, in terms of performance and disease, with the new seed. They were concerned that the hatchery bought larvae weren’t as

well acclimatized to the water and temperature conditions in their ponds.[37] To realize (and for farmers to see) the benefits of disease-free seed, NGOs encouraged farmers to change their farming practices, to farm in a more biosecure or disease-free fashion. These missing middle farmers had largely survived and farmed in a system characterized by frequent health and disease problems by developing a form of multi-cropping, farming a variety of species, and frequently re-stocking their ponds. Where possible, ponds were multi-use—the same *gher* or flooded paddy field produced rice crops in winter, as well as finfish, mud frogs, shrimp, and prawn. Farmers bought their seed and fry at regular intervals, topping up stock throughout the production period. After the summer monsoon, for example, farmers could take advantage of changing water conditions (the rains would alter water depth, as well as the salinity, oxygen content, and temperature of the ponds) by re-stocking or adding new species. Farmers would, as a result, spread the cost of seed. An added benefit was that they could harvest at various points in the season in order to take advantage of variable market prices and secure regular income to service the weekly collections of payments on their microfinance loans.[38] All this tinkering was of course counter to the ideals of disease-free farming, as each introduction to the pond risked adding disease and undermining the integrity of the system (and the point of supplying disease-free seed). So, farmers were encouraged to buy all their seed in one transaction, and to follow a batch-like production system. Doing so would reduce disease and, in turn, lessen the need for treatments.

While lowering stocking frequency seemed to reduce mortality in the ponds (though this was probably a result of reduced predation of larvae by other pond inhabitants), the effect on disease incidence was less clear. Perhaps more importantly, qualitative research suggested that the farmers were more rather than less exposed to livelihood risks once they followed the stocking guidance. By disrupting the vernacular system of managing disease and financial risks using frequent stocking and multi-cropping, farmers were more rather than less likely to

experience a disease event as economically ruinous and so turn to disease treatments as a means to rescue their livelihoods. While farmers were exasperated that these treatments were unreliable and expensive, they also said that, if they didn't use them, they "would be left with nothing." In other words, by concentrating their disease-free farming into a single species with limited numbers of harvests, they exposed themselves to more rather than less livelihood risk. In so doing, they would be more rather than less likely to turn to antimicrobial and other disease treatments.

In terms of One Health, the lesson is that the health of the system is more than incidence of disease. It is how that disease is managed that matters—and whether it is seen as something to adjust to or as something that can potentially lead to economic ruin. While reducing disease transmission is a good thing, the assumption that farmers needed to adopt a "disease-free" farming system in this case produced a risk gradient that encouraged more rather than less treatment with antimicrobials. In an economically precarious situation, there is a clear need not only to understand disease incidence, but also to appreciate the socioeconomic risks faced by the farmers. More broadly, the point of this case may be that One Health is delivered in ways that may *not* be optimal for human, animal, and environmental health, at least if the optima are measured in absolute terms. The best One Health outcome in this case might be a tolerable and manageable background noise of disease. It is the lessons learnt from the farmers—multi-cropping, frequent stocking, and agro-ecological approaches to production—that suggest living with disease and adapting farming practices to those diseases, and to other environmental challenges, offer the more sustainable pathways compared to imposed norms of biosecure farming and disease-free solutions.[39] The distinction is both clear but also subtle. One Health is not an absolute state (disease freedom)—it is a process, an approximation, where the optimum may involve several sub optima within the components.

Rethinking Optimal Outcomes

The American Veterinary Medical Association defines One Health as "the collaborative effort of multiple disciplines—working locally, nationally, and globally—to attain optimal health for people, animals, and our environment."[40] Optimization of health, it should now be clear, cannot be reduced to a simple metric, or to a state of being. The presence or absence of illness, or even more reductively, the presence or absence of specific pathogens, is an insufficient guide to the health of an environment, organism or society. Moreover, while health outcomes are undoubtedly shared across human and nonhuman communities, it may not be possible to ensure that there will be optimization of every sector or subsector of the One health circle.

The 1948 World Health Organization Constitution declared that health is the absence of illness as well as "a state of complete physical, mental, and social well-being."[41] There is of course a lot more that could be said here about health—for example, how contemporary senses of immunity draw attention not only to the constitutive role played by illness and pathogens in the continuous production of an immuno-competent body,[42] but also to the need to understand health as an ability to recover, or to adapt to disease.[43] As Porter put it, so succinctly, health is not a matter of approximations to the average, or a norm, but a matter of appropriate adaptation to environment,[44] and so, we could add, a matter of geographical specificity. We can extend this definition of human health to one that befits environments (the adaptation of ponds in Bangladesh) and of course nonhuman species. In this case optimization is not a matter of *being* disease-free, but a relational process in which the *becoming* or dynamics of microbiomes and interspecies relations are key. One Health becomes a matter of working with rather than against environments. Disease is, in this sense, about understanding not only the mechanisms associated with causative agents, but also how an environment and a host play their parts in producing pathogenicity. Health in this sense is

a matter of the mixtures and patterns of multispecies assemblages. It is the health and regulatory work of the microbiome in guts, on skin, in the soil and in ponds that matters. Work, for example, on what have been called pathobiomes—"the set of host-associated organisms (crucially encompassing prokaryotes, eukaryotes, and viruses) associated with reduced (or potentially reduced) health status, as a result of interactions between members of that set and the host"[45]—and the development of metagenomics and metabolomics, starts to open up new ways of assessing health across human-nonhuman-environment interfaces. In the ponds in Bangladesh, for example, the health of the system may be less a matter of presence or absence of a livestock pathogen, and more a matter of the relative balances between various populations of microbes, macrobes, and other physiochemical parameters. While the language of the normal and the pathological persist, the step change is clear in the sense that a healthy biome involves a range of assemblages, which may tip[46] into pathogenic arrangements through processes that involve a reduction in self-regulating behaviours.

Similar examples are found in studies of human, plant, and environmental health. The work of those in a newly re-energized field of pollution and discard studies as well as plant health is exemplary.[47] Notions of acceptable levels and assimilative capacities are being displaced by work inflected with readings of the colonial logics that stem from and fuel the errors of assuming stable chemistries and relatively fixed thresholds between contaminated and polluted media. Likewise, a "fumigatory" approach to plant and soil life in the name of crop health and market return has been fuelled by this license to pollute as well as a reductive approach to living and soil processes. Toxicology has long since moved on to understanding the synergies of materials and pollutants, while subtle shifts in holobiont relations are increasingly shown to reconfigure health and wellbeing (a holobiont is a unit of biological organization composed of a host and its associated bacteria, Archaea, viruses, protists, and fungi—it is a useful term to displace the sense of there being discrete organisms of

"monogenomic differentiated cell lines"—"we", like other organisms, are instead "far from equilibrium assemblies of highly heterogeneous cells").[48]

Exemplary work includes historical research on the under-reported illnesses of downwinders at 20th C plutonium manufacturing districts in Russia and the US, and more recently the challenge to official statistics associated with the 1986 Chernobyl accident.[49] In all cases, radioactive materials remain in the soil, water, and environment, but at concentrations and producing emissions that are conventionally reported as within acceptable levels. In these locations, health complaints including chronic syndromes, digestion problems, immune disorders, and so on, were historically dismissed as individual illnesses rather than environmentally or industrially produced. For the science studies scholar and historian Katrina Brown, working with microbiologists, the patterns of downwinders ill-health could be linked to mutations not in the patients' bodies or monogenomic differentiated cell lines, but to damage within their intestinal bacteria. Ill-health, as a result, was related not so much to an acute dose of pathological radiation, but to chronic sub-lethal exposures that affected the relations between the patient and their microbiological companions. As Tsing and colleagues summarize,[50] ill-health thus becomes a matter of suffering the ills of another.

Health, on this reading, is a matter of entanglements—being entangled with others of various kinds is key to being a healthy holobiont.[51] This social science refrain of the importance of entanglement is of course important ontologically. But the difficult question remains, how to optimize, and which of these numerous entangled relationships matter? In turn, how can a more capacious, relational, and inclusive One Health be made to work? Pathobiomes and other microbiome imaginaries can, despite the scientific enthusiasms, become bogged down in data. The promise of machine learning and hi-throughput data processing may suggest that signals can be discerned in future.[52] But the multifactorial nature of health means that the evidence base for establishing proximate and distal causes that lead

to ill health may remain illusory. They may also be unlikely to follow the same norms and criteria of the states and standards associated with legal and regulatory processes that have been utilized in the past. Rather like the dogs in Chad, the calculus may be changing from clear states or levels that are easily translated into rules and legislature, to more complex statements around healthy assemblages. The implications include a need to expand the tool kit for the governance of One Health; considering different forms and formats of evidence; adopting, where appropriate, precautionary approaches to regulation; adopting open forms of monitoring and data generation that can trigger reviews of processes or products that were previously considered safe or inconsequential.

So, in terms of optimization, there may be no straightforward answer to what is effectively a set of relations and a situation where there will be relative gains *and* losses. In other words, we may be moving away from the win-win rhetoric of One Health, and edging closer to something that is more familiar to politicians. One Health might be better characterized as something that involves winners and losers, trade-offs, compromises, and the aim will then be to find solutions that are not so much optimal but geographically appropriate, politically just, and biologically, socially, and ecologically legitimate.

A possible opening to this version of One Health would be to look towards other areas where similar issues of conditional optimization have been discussed. For example, in the related field of animal welfare studies,[53] a heuristic model can help to shape discussions of the quantity and quality of welfare. While there are reasonably robust definitions of animal welfare (the OIE defines this as applying when an animal is healthy, comfortable, well-nourished, and able to express innate behaviour and not suffering from pain, fear or distress),[54] actual or delivered welfare will depend on a trade-off between a variety of factors including markets for produce, desires of a society to sponsor or tolerate certain levels of welfare and so on. John McInerney's[55] simple model makes this trade-off function clear—as

livestock productivity increases, animal welfare may initially increase in the form of improved diet, husbandry, and removal of environmental stress, but will soon start to fall as the biological stresses of production, housing, and so on start to take their toll. At some point, the animals are pushed to their biological limits and there is a collapse—see point E on the graph in Figure F.3. For McInerney, the actual welfare that is deemed appropriate is not necessarily the optimal for the animal in question (although of course this position may be supported by many). It is rather the level, close to C on the curve, that offers the acceptable compromise between human and animal benefit. This is the point where human health and welfare may gain from food security and accessibility, while animals experience what are agreed to be acceptable welfare standards. The graph is of course too simple, and there will be many more dimensions to this issue than the two represented on the axes. The intention of the model is not necessarily to argue over the details of the metrics, or indeed to deny that many societies and livestock systems get this wrong. It is to underline that any system of "optimization" will, in all likelihood, involve complex trade-offs and compromises. These may not be acceptable to all parties and will be subject to claims and counter-claims. For our purposes, we could say that when welfare or health become more than a state of being, but involve some measure of quantity (how much health?) then there are bound to be public disputes over priorities and emphases.

Place Figure F.3 here: Conflicts between animal welfare and productivity. Source: McInerney, file:///Users/irusb/Desktop/animalwelfare.pdf, p. 30.

When the metaphysics change from things to processes, and organisms are understood as holobionts, when the evidence and knowledge base shifts and when we re-insert health into a social and economic context, then One Health becomes a more variable set of outcomes. Rather than a technical matter of assuming a positive sum game and a win-win situation, we enter a world of competing interests, alternative interventions, scarce public resources, different investment opportunities, and uncertain outcomes. It is, in other words, a

public matter—One Health is part and parcel of what might be understood as an ongoing contest about what counts as health. It is a matter for, and of, public interest.[56]

Some Conclusions

I started this Foreword by referring to the lures that are used to draw in wildfowl to a wild bird survey. The rationale for the work was to detect avian influenza in migrating birds, as they moved south and west from their summer feeding sites in Scandinavia, Siberia, and the Arctic. And the reason for doing so was largely to gauge the threat to UK poultry farming, providing early warning of transmission risk to domestic birds. In this sense, the lures configured wild birds as a threat to the economy, as reservoirs of infection and onward transmission.

The lures may also have been something of a diversion. Perhaps they, or the survey apparatus more generally, partially obscured the more worrying sense that wild birds were not so much the source *of* danger, but *in* danger. As the timing and routes of avian migrations started to alter in response to changing climates and diminished food availability; as previously discrete populations mixed in increasingly isolated and pressured feeding sites; and as global poultry expands and alters viral opportunities, we were (and are) witnessing a shift in planetary biology. Framing migrant wild birds as threats while failing to divert resources to changing livestock production and habitat depletion is akin to blaming a river for flooding. It is to mistake symptoms with causes. One Health should be an opportunity to question how human-animal-environment relations are being formatted. What, in other words, is being missed or silenced?

This widening of scope is evident in the chapters of this book, and as several authors make clear, it is in some ways an outcome of the experience of a global pandemic. While there is, and will undoubtedly continue to be, investments in searches for origins and some quite legitimate concern with the spill over events that enabled a relatively innocuous bat

coronavirus to jump species and become highly pathogenic and transmissible in people, the pandemic has also raised other concerns about shared health outcomes. Perhaps most notable of these has been the role of health inequalities in the transmission, infectivity, and health outcomes that relate to infection with SARS-CoV-2. The high prevalence, in many badly effected states, of metabolic diseases (obesity, diabetes, hyper-tension) and their uneven distribution in terms of racial and socio-economic inequalities,[57] has opened up pressing questions for One Health. The micro- and macro-impoverishment of holobionts, the effect on metabolic pathways and processes,[58] has produced a slow violence,[59] gradually and unevenly eroding the capabilities of groups of people, environments, and nonhumans, and health care systems, to adapt to disease and illness.

The questions for One Health might be more then than the economic, social, and environmental drivers of spillovers, important though these are. Critical questions include the conditions that produce infectability and increasingly uneven experiences of vulnerability. This applies to food systems and metabolic justice, dietary patterns, economic and health care systems that are all changing what it is to be a human being (a being that sleeps fewer hours, eats more carbohydrates and refined sugars, maintains a lower body temperature and is increasingly suffering the ills of another). In other words, as COVID-19 has troubled any hard distinction between communicable and noncommunicable diseases, with morbidity and mortality rates strongly correlated with those already living with chronic illnesses, it's time to loosen the obsession with pathogenic microbes, and consider what is driving pathological lives.[60]

The trap of One Health is perhaps to seduce, in its language of wholeness and integration, and to lose sight or sense of the core issues of both planetary change and of health. The veterinary science-based promoters of One Health are in some cases too wedded to an ethos of making and mending the worlds of human extraction and exploitation of

nonhuman animals and environments. We need, urgently, a One Health that is not only able to take health more seriously—as an inevitably patchy process of piecing together compromises and adaptations to the conditions of life.[61] We also need a One Health that can, and is not afraid to, open up radical questions concerning the acceleration of poor health opportunities for many if not most of the earth's inhabitants and environments.

Notes

[1] Steve Hinchliffe and Stephanie Lavau, "Differentiated Circuits: The Ecologies of Knowing and Securing Life," *Environment and Planning D: Society and Space* 31, no. 2 (2013): 259-274; Steve Hinchliffe, "Sensory Biopolitics: Knowing Birds and a Politics of Life," in *Humans, Animals and Biopolitics: The More-than-Human Condition*, eds. Kristin Asdal, Tone Druglitro, and Steve Hinchliffe (Abingdon: Routledge, 2017), 152-170. See also Keck, this volume.

[2] Cassidy rightly identifies the anthropocentrism of much of the early One Health literature in comparative medicine and epidemiology. Much of that literature treats nonhuman health in the service of human health. As should become clear, this instrumentalism negates to ask the critical questions that mark a more radical sense of the One Health project. Angela Cassidy, "Humans, Other Animals and 'One Health' in the Early Twenty-First Century," in *Animals and the Shaping of Modern Medicine: One Health and Its Histories*, eds. Abigail Woods et al. (London: Palgrave Macmillan, 2017), 193-236.

[3] Melanie J. Rock, Dawn Rault, and Chris Degeling, "Dog-Bites, Rabies and One Health: Towards Improved Coordination in Research, Policy and Practice," *Social Science & Medicine* 187 (2017): 126-133. See also Nadal, this volume.

[4] Sarah Cleaveland et al., "Rabies Control and Elimination: A Test Case for One Health," *Veterinary Record* 175, no. 8 (2014): 188-193.

[5] Krithika Srinivasan et al., "Reorienting Rabies Research and Practice: Lessons from India," *Palgrave Communications* 5, no. 1 (2019): 152.

[6] Katie Hampson et al., "Transmission Dynamics and Prospects for the Elimination of Canine Rabies," *PLOS Biology* 7, no. 3 (2009): e1000053.

[7] Jakob Zinsstag et al., "From 'One Medicine' to 'One Health' and Systemic Approaches to Health and Well-Being," *Preventative Veterinary Medicine* 101, nos. 3-4 (2011): 148-156.

[8] Cleaveland et al., "Rabies Control," 189.

[9] Alicia Davis and Jo Sharp, "Rethinking One Health: Emergent Human, Animal and Environmental Assemblages," *Social Science & Medicine* 258 (2020): 1-8.

[10] Cleaveland et al., "Rabies Control," 192.

[11] Susan Craddock, "Precarious Connections: Making Therapeutic Production Happen for Malaria and Tuberculosis," *Social Science & Medicine* 129 (2015): 36-43; Linsey McGoey, *No Such Thing as a Free Gift: The Gates Foundation and the Price of Philanthropy* (London: Verso, 2015).

[12] Emma Mawdsley, "Development Geography II: Financialization," *Progress in Human Geography* 42, no. 2 (2016): 264-274.

[13] Susan Erikson, "Global Health Futures?," *Medicine Anthropology Theory* 6, no. 3 (2019): 77-108.

[14] Mawdsley, "Development Geography II," 268.

[15] Erikson, "Global Health Futures?"

[16] Andrew Lakoff, "Two Regimes of Global Health," *Humanity: An International Journal of Human Rights, Humanitarianism, and Development* 1, no. 1 (2010): 59-79.

[17] Mawdsley, "Development Geography II," 271.

[18] Cleaveland et al., "Rabies Control," 192.

[19] The term is introduced in Steve Hinchliffe et al., *Pathological Lives: Disease, Space and Biopolitics* (London: Wiley Blackwell, 2016).

[20] Nancy Leys Stepan, *Eradication: Ridding the World of Diseases Forever?* (Ithaca: Cornell University Press, 2011).

[21] Donald R. Hopkins et al., "Dracunculiasis Eradication: Neglected No Longer," *American Journal of Tropical Medicine and Hygiene* 79, no. 4 (2008): 474-479.

[22] See the different treatments in the chapters by Squier and Kristensen, this volume.

[23] Ewen Callaway, "Dogs Thwart Effort to Eradicate Guinea Worm," *Nature* 529, no. 7584 (2016): 10-11.

[24] Robbie A. McDonald et al., "Ecology of Domestic Dogs *Canis Familiaris* as an Emerging Reservoir of Guinea Worm *Dracunculus Medinensis* Infection," *PLOS Neglected Tropical Diseases* 14, no. 4 (2020): 1-12; Donald R. Hopkins et al., "Dracunculiasis Eradication: Are We There Yet?," *American Journal of Tropical Medicine and Hygiene* 99, no. 2 (2018): 388-395, 388.

[25] Even in human health cases, verification of the ends of a disease may be less straightforward. See Vargha's account of eradication of Polio in Hungary. Dóra Vargha, *Polio Across the Iron Curtain: Hungary's Cold War with an Epidemic* (Cambridge: Cambridge University Press, 2018).

[26] Jared K. Wilson-Aggarwal et al., "Spatial and Temporal Dynamics of Space Use by Free-Ranging Domestic Dogs *Canis Familiaris* in Rural Africa," *Ecological Applications* 31, no. 5 (2021): 1-12.

[27] Neil Boonham et al., "A Pond-Side Test for Guinea Worm: Development of a Loop-Mediated Isothermal Amplification (LAMP) Assay for Detection of *Dracunculus Medinensis*," *Experimental Parasitology* 217 (2020): 1-4.

[28] Warwick Anderson, "Natural Histories of Infectious Disease: Ecological Vision in Twentieth-Century Biomedical Science," *Osiris* 19 (2004): 39-61.

[29] Christopher J. L. Murray et al., "Global Burden of Bacterial Antimicrobial Resistance in 2019: A Systematic Analysis," *The Lancet* 399, no. 10325 (2022): 629-655.

[30] T. P. Robinson et al., "Antibiotic Resistance is the Quintessential One Health Issue," *Transactions of the Royal Society of Tropical Medicine and Hygiene* 110, no. 7 (2016): 377-380.

[31] Ibid., 379.

[32] G. D. Stentiford et al., "Sustainable Aquaculture through the One Health Lens," *Nature Food* 1, no. 8 (2020): 468-474.

[33] David C. Little et al., "Sustainable Intensification of Aquaculture Value Chains Between Asia and Europe: A Framework for Understanding Impacts and Challenges," *Aquaculture* 493 (2018): 338-354.

[34] Grant D. Stentiford et al., "New Paradigms to Help Solve the Global Aquaculture Disease Crisis," *PLoS Pathogens* 13, no. 2 (2017): 1-6.

[35] Steve Hinchliffe, Andrea Butcher, and Muhammad Meezanur Rahman, "The AMR Problem: Demanding Economies, Biological Margins, and Co-Producing Alternative Strategies," *Palgrave Communications* 4 (2018): 1-12.

[36] Felipe C. Cabello et al., "Aquaculture as Yet Another Environmental Gateway to the Development and Globalisation of Antimicrobial Resistance," *The Lancet Infectious Diseases* 16, no. 7 (2016): e127-e133; Nick G. H. Taylor, David W. Verner-Jeffreys, and Craig Baker-Austin, "Aquatic Systems: Maintaining, Mixing and Mobilising Antimicrobial Resistance?," *Trends in Ecology and Evolution* 26, no. 6 (2011): 278-284.

[37] Steve Hinchliffe et al., "Production Without Medicalisation: Risk Practices and Disease in Bangladesh Aquaculture," *Geographical Journal* 187, no. 1 (2021): 39-50.

[38] Ibid.

[39] Hinchliffe et al., "The AMR Problem"; Steve Hinchliffe, "Postcolonial Global Health, Post-Colony Microbes and Antimicrobial Resistance," *Theory, Culture & Society* (2021): 145-168.

[40] One Health Initiative Task Force, "One Health: A New Professional Imperative," American Veterinary Medical Association, 2008, https://www.avma.org/sites/default/files/resources/onehealth_final.pdf.

[41] "Constitution of the World Health Organization," World Health Organization, 2022, https://www.who.int/about/governance/constitution.

[42] Warwick Anderson and Ian R. MacKay, *Intolerant Bodies: A Short History of Autoimmunity* (Baltimore: Johns Hopkins University Press, 2014).

[43] Georges Canguilhem, *The Normal and the Pathological*, trans. Carolyn R. Fawcett (New York: Zone Books, 1991).

[44] Roy Porter, "Before Foucault," *London Review of Books* 12, no. 2 (1990), https://www.lrb.co.uk/the-paper/v12/n02/roy-porter/before-foucault.

[45] David Bass et al., "The Pathobiome in Animal and Plant Diseases," *Trends in Ecology & Evolution* 34, no. 11 (2019): 996-1008.

[46] The notion of tipping points was used in relation to disease and livestock in Steve Hinchliffe, et al., "Biosecurity and the Topologies of Infected Life: From Borderlines to Borderlands," *Transactions of the Institute of British Geographers* 38, no. 4 (2013): 531-543.

[47] Max Liboiron, *Pollution is Colonialism* (Durham: Duke University Press, 2021). Julie Guthman, *Wilted: Pathogens, Chemicals and the Fragile Future of the Strawberry Industry* (Oakland: University of California Press, 2019).

[48] John Dupré, *The Metaphysics of Biology* (Cambridge: Cambridge University Press, 2021).

[49] Kate Brown, *Manual for Survival: A Chernobyl Guide to the Future* (New York: W.W. Norton, 2019).

[50] Anna Lowenhaupt Tsing et al., eds., *The Arts of Living on a Damaged Planet* (Minneapolis: University of Minnesota Press, 2017).

[51] Alex M. Nading, "Humans, Animals and Health: From Ecology to Entanglement," *Environment and Society: Advances in Research* 4, no. 1 (2013): 60-78; Alex M. Nading, *Mosquito Trails: Ecology, Health, and the Politics of Entanglement* (Oakland: University of California Press, 2014).

[52] Kristen D. Curry, Michael G. Nute, and Todd J. Treangen, "It Takes Guts to Learn: Machine Learning Techniques for Disease Detection From the Gut Microbiome," *Emerging Topics in Life Sciences* 5, no. 6 (2021): 815-827.

[53] Henry Buller and Emma Roe, *Food and Animal Welfare* (London: Bloomsbury Publishing, 2019).

[54] "Introduction to the Recommendations for Animal Welfare," OIE, 2018, https://www.oie.int/fileadmin/Home/eng/Health_standards/tahc/2018/en_chapitre_aw_introduction.htm.

[55] John McInerney, "Animal Welfare, Economics and Policy," The National Archives, February 2004, https://webarchive.nationalarchives.gov.uk/ukgwa/20110318142209/http://www.defra.gov.uk/evidence/economics/foodfarm/reports/documents/animalwelfare.pdf.

[56] Stephen Hinchliffe, Lenore Manderson, and Martin Moore, "Planetary Healthy Publics After COVID-19," *The Lancet Planetary Health* 5, no. 4 (2021): e230-e236.

[57] Anthony Ryan Hatch, *Blood Sugar: Racial Pharmacology and Food Justice in Black America* (Minneapolis: University of Minnesota Press, 2016).

[58] Hannah Landecker, "Postindustrial Metabolism: Fat Knowledge," *Public Culture* 25, no. 3 (2013): 495-522.

[59] Lauren Berlant, "Slow Death (Sovereignty, Obesity, Lateral Agency)," *Critical Inquiry* 33, no. 4 (2007): 754-780; Rob Nixon, *Slow Violence and the Environmentalism of the Poor* (Cambridge: Harvard University Press, 2013).

[60] Hinchliffe et al., *Pathological Lives*.

[61] Steve Hinchliffe, "More than One World, More than One Health: Re-Configuring Interspecies Health," *Social Science & Medicine* 129 (2015): 28-35.