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The dawn of Structural One Health: A new science tracking disease emergence along circuits of capital

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ABSTRACT

The One Health approach integrates health investigations across the tree of life, including, but not limited to, wildlife, livestock, crops, and humans. It redresses an epistemological alienation at the heart of much modern population health, which has long segregated studies by species. Up to this point, however, One Health research has also omitted addressing fundamental structural causes underlying collapsing health ecologies. In this critical review we unpack the relationship between One Health science and its political economy, particularly the conceptual and methodological trajectories by which it fails to incorporate social determinants of epizootic spillover. We also introduce a Structural One Health that addresses the research gap. The new science, open to incorporating developments across the social sciences, addresses foundational processes underlying multispecies health, including the place-specific deep-time histories, cultural infrastructure, and economic geographies driving disease emergence. We introduce an ongoing project on avian influenza to illustrate Structural One Health's scope and ambition. For the first time researchers are quantifying the relationships among transnational circuits of capital, associated shifts in agroecological landscapes, and the genetic evolution and spatial spread of a xenospecific pathogen.

1. One Health and the social sciences

The new 'One World-One Health' approach integrates investigations of wildlife, livestock, crop, and human health in an ecosystemic context (Zinsstag, 2012; van Helden et al., 2013; Barrett and Osofsky, 2013). The approach convenes medical doctors, veterinarians, and ecological scientists under the rubric many species share infectious, chronic and environmental illnesses (Hueston et al., 2013). The approach is not without precedence. Calvin Schwabe's (1984) 'One Medicine,' the 'Disease in Evolution' conference at Woods Hole, and investigators as far back as social medicine founder Rudolf Virchow and 18th century veterinarian Félix Vicq-d'Azyr connected human and animal health within varying degrees of social and ecological contextualization (Wilson et al.,. 1994; Saunders, 2000; Morens, 2003). The renewed interest appears driven as much by practical matters as by theoretical development in related fields such as ecohealth (Webb et al., 2010) and complexity science (Carpenter et al., 2009). The complications associated with the surprising spillover of highly pathogenic influenza A (H5N1) ('bird flu') from poultry to humans at century's end galvanized international health agencies to gather scientists across disciplines to address influenza and other emergent diseases (Anderson et al., 2010).

The new One Health has been presented as a crucible in which to test combinations of specialist approaches in population health (Kahn et al., 2012). The animal and human diseases into which it is now most difficult to intervene arise from and spread by a multitude of causes interacting at multiple scales and across biocultural domains. A variety of epistemologies are required to address such

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infections. Indeed, retrospectively many of today's most common human infections first arose in ancient civilizations by way of such synergies (McNeill, 1977/2010). Domesticated stock served as sources for human diphtheria, influenza, measles, mumps, plague, pertussis, rotavirus A, tuberculosis, sleeping sickness, and visceral leishmaniasis (Pearce-Duvet, 2006; Wolfe et al., 2007). Ecological changes brought upon landscapes by human intervention selected for spillovers of cholera from algae, malaria from birds, and HIV/AIDS, dengue fever, malaria, and yellow fever from wild primates.

The new pathogens stimulated innovations in medicine and public health, including individual treatment and prophylaxes, land and marine quarantines, compulsory burial, isolation wards, water treatment, and subsidies for the sick and the unemployed (Watts, 1997; Colgrove, 2002). Each of the series of agricultural and industrial inventions to follow accelerated demographic shifts and new settlement and rejuxtaposed potential host populations, prompting additional rounds of novel spillover (Kock et al., 2012). Environmental impacts, climate change among them, have since scaled geological (Ding et al., 2013). While producing an unprecedented array of commodities, attendant increases in resource extraction, producing material and conceptual rifts between economy and ecology, have degraded habitats, biodiversity, ecosystem function, resource bases, waterways, soil nutrients, and oceanic stock (McMichael, 2009; Foster et al., 2010). The impacts have together promoted disease emergence across multiple host taxa (Jones et al., 2013).

In particular, the 'Livestock Revolution,' in which the breeding, processing and distribution of fast-growth livestock are vertically integrated under a few large agribusinesses, makes repeated appearances across these latest impacts (Magdoff and Tokar, 2010). Industrial stockbreeding drives as much as services a new demand in meat protein, particularly in so-called developing countries, where, like its Neolithic predecessors, it promotes pathogen spillover (Jones et al., 2013; Liverani et al., 2013). Livestock effects are indirect as well. While the sector's growth presents economic opportunities, competition from integrated producers marginalizes smallholders out of markets (de Haan et al., 2010; McMichael, 2012). In turn, the resulting food insecurity, environmental destruction, and perceptions thereof serve as rationales for a particular capital-securitized science tied into spreading the very agrifood model precipitating cycles of economy and disease (Davis, 2007; Wallace and Kock, 2012; Sparke, 2014).

Social scientists have begun to help catalog the mechanisms by which such disease spillover is socially mediated. Anthropologists Goldberg et al. (2012) describe the Kibale EcoHealth Project in Kibale National Park in western Uganda, testing for the area-specific connections among human health, animal health and the surrounding landscape, including population growth, forest fragmentation, rural poverty, cultural beliefs, and shifts in agriculture. Multispecies infection dynamics there, including for *E. coli,* appear as connected to higher-level agroecological changes as to behavioral practices directly related to transmission. For instance, humans tending livestock proved at elevated risk of carrying *E. coli* strains specific to local wild primates increasingly marginalized to dwindling forests. Red-tailed guenons raiding crops out of said forests tended to carry *E. coli* characteristic of humans and livestock.

Other studies have investigated disease pathways appropriate to more industrialized contexts. For example, Paul et al. (2013) apply a value chain analysis to traditional poultry production in Phitsanoulok, Thailand. The team found across 28 poultry collectors, slaughterhouses and market retailers that collectors—intermediaries between farmers and slaughterhouses—played an unrecognized role in spreading HPAI H5N1 in Phitsanoulok. The rapid destocking of poultry upon an outbreak facilitated H5N1 spread and appeared influenced by risk perception, economic margins, and compensation for the players along the commodity chain.

Other social science has positioned One Health within local and global political economies. Giles-Vernick et al. (2010), for instance, review the historical roots of a number of pandemics with the expectation comparative studies should help divulge unexpected differences and similarities across outbreaks. Such work aims to draw out the complexities inherent to societal responses that single site studies routinely miss, including "the unequal burdens of suffering … subsumed under the rubric of globalization." Sparke and Anguelov (2012) situate the politics of epidemiological knowledge within such a socioeconomic divide between the global North and South, specifically within risk management, access to medicines, media portrayals of risk, and the emergence of new diseases in the first place. Forster and Charnoz (2013) find these inequalities also arise out of a coercive "global health diplomacy"—both governmental and philanthropic—ostensibly undertaken to bridge the divide. Keck (2010) describes such power dynamics as an extension of colonial medicine. The contests are part and parcel of higher-order struggles over the political course of economically developing "sentinel borderlands" where new epizootics arise and at the epistemological junctures where disciplines meet.

Research gaps remain, however. In this paper we first critically review One Health as conceived to this point, suggesting additional points of departure for social scientists of a variety of stripes, including in medical anthropology (Kleinman et al., 2008; Lowe, 2010), ecosocial epidemiology (Krieger, 2001), biopolitics (Braun, 2007), and the political ecology of health (Rayner and Lang, 2012), all of which have addressed various aspects of the relationship between social science and epidemiology. As integral as these approaches are to understanding the social context of population health, none to date has pursued statistical tests of what Krieger (2001) and others (*e.g.,* Bond, 2012; Collard and Dempsey, 2013; Hinchliffe et al., 2013) have hypothesized are the likely connections between global capital accumulation and determinants of ecosystemic health.

To that aim we also introduce here an approach that seeks to model the mechanisms by which the broader socioeconomic context largely missing from One Health helps select for xenospecific spillover. Specifically, for the first time in any field we introduce ongoing research *quantifying* the relationship between the circuits of capital out of which many new diseases emerge and their subsequent dynamics, including, from the vantage point of pathogens, their genetic evolution and sociospatial spread. That is, we propose a Structural One Health that empirically formalizes the connections among capital-led changes in the landscape and shifts in wildlife, agricultural, and human health. Should such efforts eventually succeed, researchers will be able to identify the statistically supported combinations of local agroecological circumstances and economic relations that—extending out beyond specific epicenters—drive disease spillover across species.

2. The science and political economy of One Health

Integrating health studies across species appears a step forward for disease prediction and control. A literature search by Rabinowitz et al. (2013) showed a series of studies offering evidence for the feasibility of intersectoral cooperation, including the xenospecific benefits of animal vaccination. Rabinowitz et al. review other studies showing improvement in predicting site-specific disease dynamics and in implementing successful intervention. As presented so far, however, the One Health approach also misses key sources of causality, an omission that for some of its analyses may reverse initial conclusions. For instance, descriptions of efforts in

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disease control can conflate proximate risk factors—and the contact tracing, vaccination, culling, and biosecurity deployed in response—with the underlying *causes* of an outbreak (De Vreese, 2009). A disease is synonymous neither with its pathogen, nor a map of its infecteds, whether or not either is placed within a One Health context that acknowledges the functional ecologies humans, livestock and wildlife share.

Among many such investigations, there is Preston et al.'s (2013) description of the effects of Peruvian land use on disease emergence. While the specifics as to deforestation's effects on Amazonian malaria are rigorously documented, the study is emblematic of a model of health that confounds where a pathogen emerges with the geography of causality (Wallace, 2013a). Such absolute geographies often miss the sociospatial relations across global economic actors, the effects of which can reach into the very mechanics of modeling (Yeung, 2005). In presenting updated maps of global livestock, Robinson et al. (2014) report,

> As [agricultural] production intensifies it becomes increasingly detached from the land resource base (for example as feeds are brought in that are grown in completely different places) and thus more difficult to predict based on spatial, agro-ecological variables. The effect is particularly marked for chickens and pigs, where the locations of intensive farming units often have more to do with accessibility to markets or to inputs of one sort or another, than to the agro-ecological characteristics of the land that can be quantified through remotely sensed variables.

The consequences for epidemiology extend beyond the technical. Harking back to the core assumptions underlying colonial medicine, which Tilley (2004) notes included at its peak its own "ecology of complexity," an absolute One Health can steer scientists of what Connell (2007) identified as a modern-day North American and European metropole into lecturing the global South about deforestation and disease risk. For instance, Robbins (2012) quotes one ecohealth scientist,

> By mapping encroachment into the forest you can predict where the next disease could emerge … So we're going to the edge of villages, we're going to places where mines have just opened up, areas where new roads are being built. We are going to talk to people who live within these zones and saying, 'what you are doing is potentially a risk.'

While the impulse is understandable, such environmental crises are in actuality confined to no outbreak zone, and are presently driven largely by structural adjustment of a variety of permutations and a doctrine of export economics originating at capital's core (Foster et al., 2010; Gindin and Panitch, 2012). The capital backing the kinds of development and production driving disease emergence in the underdeveloped parts of the globe potentially reverses causality, turning New York, London, and Hong Kong, key centers of global capital, into three of the world's worst 'hotspots' instead (Mansfield et al., 2010; Liberti, 2011/2013; Pearce, 2012). Alongside sovereign wealth funds, state-owned enterprises, and governments, private equity in the form of agribusiness and agrifood companies, biofuels developers, and private institutional investors—mutual funds, banks, pension funds, hedge funds, university endowments, and private equity funds—are accelerating purchases of farmland in the global South, consolidating domestic food production there, speculating land prices, and exporting output to the global market at grave costs to smallholders and the environment alike (Kaufman, 2011; Daniel, 2012; Wohns, 2013). The Land Matrix Observatory (2014) lists 959 transnational land deals concluded worldwide as of June 2014, covering nearly 36 million hectares. The Oakland Institute (2011) estimated $500 million invested in African farmland alone, with expectations of 25% returns from production and land appreciation on leases running for as long as 99 years and, depending on the deal, unlimited water rights, profit and equity repatriation, and exemptions or reductions in custom duties, VAT taxes, and profit taxes.

In this way One Health *as a science* can obfuscate context, even in the course of describing multiple sources of epidemiological cause and effect. Kahn et al. (2012), among a variety of examples, describe the process by which Nipah virus emerged in 1998 Malaysia when deforestation destroyed fruit bat habitat. The bats migrated to trees nearby livestock pens where they spread Nipah to pigs, from which humans were subsequently infected. As in other studies, Kahn et al.'s description leaves the companies and land deals backing the hog intensification associated with the spillover unnamed, as are the broader economic shifts in regional stock-breeding undergirding local dynamics (Pulliam et al., 2012; Otte and Grace, 2013).

One Health practitioners are certainly cognizant of the notion of a larger context. Considerable attention is paid to the epistemological boundaries of the perspective. In writing cogently on the economic and social inputs on disease emergence for one of a series of *Ecohealth* editorials, Zinsstag et al. (2012) propose,

> Intercultural work on the human—animal relationship requires a clarification of one's own perspective in a self-reflective way. 'What is my personal cultural/and ethical background that determines my relationship with animals and my concept of one health?' Answers critically determine the emotional or financial value assigned to animals. Could this lead to a new subjectivism in Science? 'One health', for example, can be influenced by philosophical ramifications, that determine the method of economic analyses of the cost of infections that are transmissible between humans and animals …

The research out of such a formulation is cast in the mildest of cross-cultural terms: pursue One Health from other vantage points. Such a modest expectation may limit the One Health produced. Little effort appears to have been made to identify specific owners and producers. Disease actors are classed in abstractions—susceptibles, infected, and recovered—coded for simultaneous equations that can disappear socialized epidemiologies (Gould, 1993). Even the 'socio-economic' work under such a rubric has until now tended toward tracing out the broadest of logistics underlying the geography of disease. Hosseini et al. (2010), for instance, combine direct and indirect airline flights, total poultry and swine trade, and healthcare spending as a marker of a country's ability to detect new cases to retrospectively project early spread of swine flu H1N1 (2009) (and ostensibly other pandemic influenzas to follow).

Such studies are useful. There is great value in discovering how to block a novel pathogen from spreading through animals and humans alike, whatever the system in which we find ourselves historically. At the same time, there are profound costs associated with reifying a status quo that brought about the threat in the first place. Such work can advance a technicism that acts as an ideology in absentia, implicitly delegitimizing alternatives by way of a narrow approach to an unexamined grand project already under way (Mészáros, 2010). Indeed, if the vantage points proposed are limited enough, disease research presumes state and market neoliberalism as a part of the natural order even should other studies show the system's mechanisms are central to the problem of disease (Wallace and Kock, 2012).

Such a political economy raises the issue whether the current epidemiological infrastructure can address the totality of inputs impinging upon the problems it addresses (Wallace, 2012). How,

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for one, does the World Bank or the World Health Organization approach outbreaks that originate with the very institutions on which the organizations depend for funding and legitimization? One recent World Bank report offers a well-documented economic case for One Health. Smith et al. (2012) aim at convincing the world's richest countries to invest in ecohealth and conservation by appealing to the underlying costs of a failure to act: at least US$80 billion in losses from Nipah, West Nile Fever, SARS. HPAI, BSE and Rift Valley Fever in 1997–2009. The authors propose that paying a little now—US$1.9 billion to US$3.4 billion annually across 139 countries—can prevent considerable epidemiological damage, including in the face of a low year-to-year probability a deadly pandemic will strike. The gains should compound, advancing campaigns in poverty reduction, food security and food safety. The report also positions One Health, sharing lab and vaccination costs across animal and human projects, as a way of institutionalizing the kinds of service consolidations routinely proposed under the doctrine of budgetary austerity (*e.g.,* Stine and Chokshi, 2012).

The NGO literature is filled with such promethean appeals. The reports also regularly omit addressing capital's structural momenta growing evidence indicates help select for deadly pathogens (Otte et al., 2007; Graham et al., 2008; Leibler et al., 2009; Wallace, 2009; Drew, 2011; Jones et al., 2013). Together the latter citations describe a system at best insensitive to the platforms it creates for pathogen emergence. Its production cycles degrade ecosystemic resilience to disease as natural resources are transformed into commodities, complicate epidemiological interventions by treating humans and animals as markets and commodities first, and globalize the transport of goods, people, livestock, and pathogens. Indeed, following Moore (2011) capitalist production does not *have* an epidemiology so much as it *is* an epidemiology.

The failure to address such a fundamental context may itself serve a purpose, however unintended. Within the current global recession, epidemiological interventions increasingly represent declensionist rationales for the neoliberal land grabs, wholesale deforestation, and agricultural intensification that underpin many of the epizootic outbreaks in the first place (Davis, 2006; Wallace and Kock, 2012). The outbreaks of the global South are presented as due cause for clearing the field of all agricultures and alternate economies save the most highly capitalized and 'biosecure', which in actuality, suffering diseconomies of scale, have been implicated in recent outbreaks and new strains: among them, LPAI, HPAI, Q-fever, foot-and-mouth disease, porcine reproductive and respiratory syndrome virus, the Salmon louse *Lepeophteirus salmonis*, and West African Ebola (Myers et al., 2006; Gilchrist et al., 2007; Evans et al., 2008; Wallace, 2009; Mennerat et al., 2010; Leibler et al., 2010; Van Boeckel et al., 2012a; Smit et al., 2012; Ercsey-Ravasz et al., 2012; Liverani et al., 2013; Bausch and Schwarz, 2014). Specifically, genetic monocultures, high population densities, rapid throughput, and increased exports appear to promote greater pathogen spread and evolution.

On the other hand, other One Health work appears immediately amenable to expanding its purview. Engering et al. (2013) place infectious disease events into four categories. While each category has its own set of typical drivers as the authors describe them, each also has its own apparent link to production and capital flows. For example, endemic diseases, the first of Engering et al.'s categories, are important mainly in underdeveloped countries and are often associated with poverty (Alsan et al., 2011). The emergence of pathogens in novel hosts is related to the economic models underlying the destruction of wildlife habitat, from which wildlife diseases spill over into humans, as well as those backing poultry and livestock production (Jones et al., 2013). Pathogen introgressions are oft-related to trade or more gradual expansions brought about by climate change and shifts in land use (Blackwell, 2010; Brückner, 2012). Finally, the emergence of pathogens with novel traits by virulence jump or antimicrobial resistance has been connected repeatedly to intensified husbandry and preventive antibiotic use in livestock (*e.g.,* Zhu et al., 2013).

3. Three postulates of a Structural One Health

What would an alternate science look like? At its most comprehensive, a Structural One Health could include all the foundational processes underlying health ecologies, including, but not limited to, the ownership and production, deep-time historical holdovers, and cultural infrastructure behind the landscape changes driving health threats. Wallace, Bergmann, Hogerwerf, and Gilbert (2010), for instance, explain influenza in southern China in terms of a 'historical present' within which multiple virulent recombinants arise out of a mélange of agroecologies originating at different times by both path dependence and contingency: in this case, ancient (rice), early modern (semi-domesticated ducks), and present-day (poultry intensification).

Such a One Health would act as a base upon, or limits within, which other approaches respond to their own problematics. The closer the approach is to the base of the schematic pyramid relating health approaches shown in Fig. 1, the broader the set of disciplines that are essential for researching a disease, as well as for the balance of positive and negative impacts of potential interventions. Mechanisms promoting disease at the base of the pyramid may be located elsewhere in time and space than the actual disease, including circuits of capital and historical practices. Mechanisms at the top of the pyramid are directly connected to disease dynamics (such as pathogen transmission, dietary habits of individuals, etc). The schematic is clearly an oversimplification, omitting complex interactions across conceptual scales, but, as its Thai example hints, may offer a start for conceptualizing how disease vulnerabilities emerge out of structural processes that, impacting ground zeros both directly and indirectly, may also originate distally in time, space and causality.

The geographically explicit program could be supplemented with a 'life history' perspective that tracks the means by which market demands upon livestock production at the levels of the lab, barn and/or commodity chain shape disease dynamics (Allen and Lavau, 2014). Alternately, traditional mathematical epidemiology has already begun to merge economic and disease modeling (Boni et al., 2013). Such agricultural microeconomics could be expanded to broader political economies of disease spillover. As we will explore below, other additions are feasible. In this section we introduce three starter postulates around which such a wide array of research efforts could be organized.

3.1. Differentiate domains of crisis

Fig. 1 suggests some of the crises and opportunities to which various agroecological actors, human and animal alike, respond emerge across a broad scope of causes, wider even than nascent One Health has proposed to this point.

As the previous section intimated, the distinction between types of crisis is definitional, framing the very nature of the diseases described. Mészáros (2012) differentiates between episodic or periodic crises resolved within the established framework and foundational crises that affect the framework itself. In the latter structural crises, unfolding in an epochal fashion through the very limits of a given order, the systemic contradictions start to run up against each other. As the World Bank example exemplified, palliative efforts in the name of the system that brought about the calamities may deepen the very crisis such efforts were ostensibly undertaken to alleviate. It follows unpacking the broader

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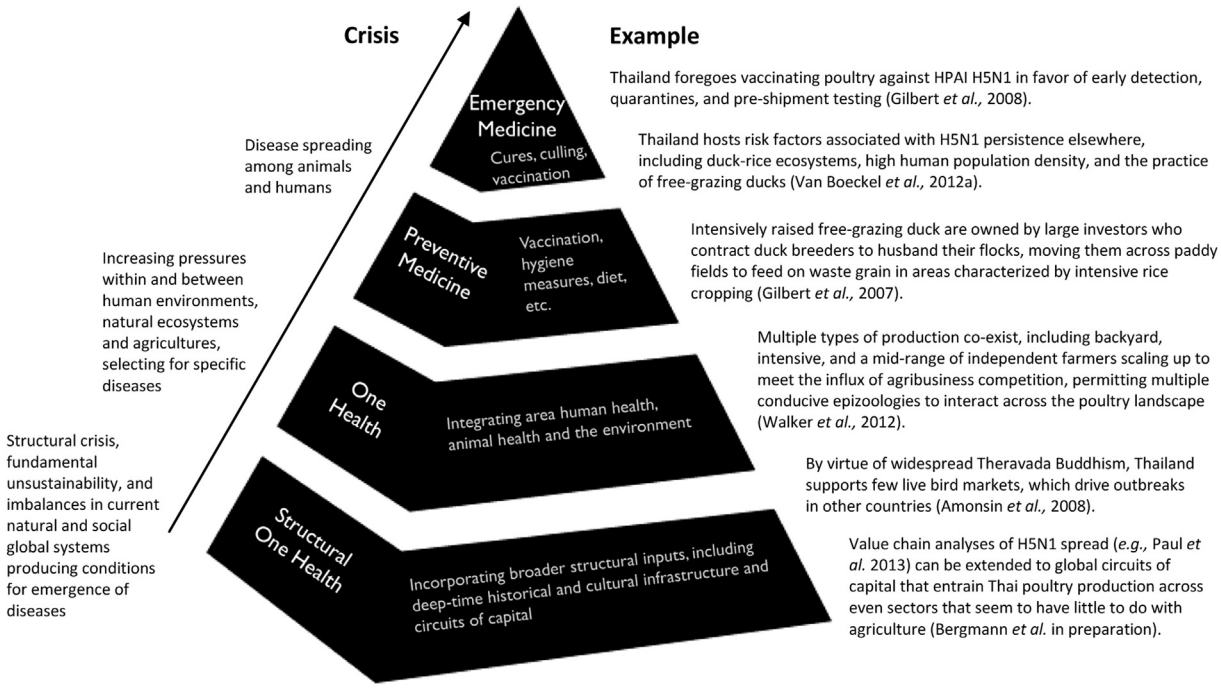

Fig. 1. Schematic pyramid of health approaches and interventions. Structural One Health investigates the broader context of a disease, including out beyond the local, more proximate mechanisms of emergence on which more episodic One Health focuses. Preventive and emergency medicine are deployed in response to threats on the health of specific populations and individuals. For all mechanisms that promote disease (under 'crisis'), the proximity in space, time and causal origin to any given outbreak increases up the pyramid. The relative importance of each point along the scale is dependent on the collective interplay between all parts of the pyramid. An array of inputs and outcomes for highly pathogenic avian influenza H5N1 in Thailand is shown across the schematic (Amonsin et al., 2008; Gilbert et al., 2007; Gilbert et al., 2008; Walker et al., 2012).

economies—financial, political and epistemological—upon which institutions and dominant paradigms depend is a critical part of a systemic characterization of health crises (Mayer, 1996; Farmer, 2001; Herz, 2013).

Such contextualization can be extended out beyond descriptive caveats and empirically operationalized. For instance, the episodic changes One Health addresses can be tracked as the overflow of capital-structured regime shifts from one ecosocial equilibrium to another as measured by Ives models of stochastic resilience (Ives, 1995; Armitage and Johnson, 2006; Hornborg, 2009).

3.2. Let the scope of the crisis define the questions addressed

The variables One Health scientists include in their models are a social decision (Levins, 1998; Leach and Scoones, 2013). What researchers choose to make internal or external to a model, including which data to concatenate or exclude, can have a significant impact on its outcome. An analysis conducted under an open sociality, one that simultaneously articulates the social processes under which the science is practiced, can modify the very premises under which the project is initiated. Indeed, such an exploratory approach may circumvent the distinction between structural and episodic. The nature of the health problems studied may suggest more aleatory and anti-foundational resolutions (Gibson-Graham et al., 2013).

For instance, Fearnley (2013) tracked the mechanism by which the science of one group of One Health practitioners was forced into matching the conceptual flexibility of the problem they addressed. The team aimed to study how zoonotic influenzas emerged in and around Poyang Lake, China, thought to be a source of multiple recombinants (Takekawa et al., 2010a,b). The researchers discovered the distinction between domestic poultry and wild waterfowl, a key premise of their study (and of the larger literature), to be effectively nonsensical (Fig. 2),

> When [Food and Agriculture Organization ecologist Scott Newman] visited Wang's farm, the Wang family graciously invited him for lunch, refusing to be dissuaded from their misrecognition of Newman as an American investor. Showing him the flock of swan geese hundreds strong, as well as mallard ducks, Wang proudly told Newman that bird production could easily be increased, and birds could be exported overseas. Wang also emphasized that the wildness (*yexing*) of his geese made them particularly valuable.

Here, the relationship between farming and the epizootic research around it becomes dynamically codetermined, if on terrain far different than the agribusiness-university complex. As Fearnley describes, Poyang farmers repeatedly manipulate the distinction between wild and domestic as an economic signifier, producing new meanings and values, including in response to the very epidemiological alerts issued in kind. In turn, the One Health team, intent on learning how recombinant influenzas actually emerge, chose against their field's practice to let the crisis define the study question, integrating economy and ecology.

3.3. Integrate modes of causality

Integration extends beyond introducing different disciplines, however. Hoffman (2011) contends institutionalized interdisciplinarity in more capitalized economies can cater to the new labor demands of profit-based state and private universities and the 'problem-driven' research championed by private foundations and corporate R&D. Levins and Lewontin (2007) include in the resulting epistemological fallout a series of ontological dichotomies scientists, epidemiologists included, traffic into their own work: between chance and necessity, randomness and determinism, organism and environment, and nature and society.

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Fig. 2. Semi-domesticated ducks returning to their host farm of their own volition after a day out on Poyang Lake, Jiangxi Province, China, October 2007. Photo by Marius Gilbert.

A Structural One Health might better match the pathogens it studies by integrating across these divisions. For instance, in a vital contribution Leibler et al. (2009) pursue an ecohealth of industrial animal production, describing disease vulnerabilities at selected links in the value chain. Some nodes in poultry production, for instance, are more vulnerable to producing influenza outbreaks than others. Their analysis, as sophisticated as any in One Health to date, also reproduces one of the field's faulty presuppositions. Although as the team describes, biology and economy—bird ontogeny and commodity production—operate in parallel, even interacting with each other, another possibility goes unaddressed. Biology and economy also repeatedly meld into composite objects, often with complex webs of human, livestock and pathogen agency (Wallace and Wallace, 2014). Wallace (2013b), for instance, hypothesizes avian influenza has converged upon agribusiness's production schedule, with the virus 'husbanding' cohorts of infected birds not for market but the next available barn of susceptibles.

4. Operationalizing a Structural One Health

Geographer Luke Bergmann's group extends the convergence of biology and economy beyond a single commodity chain and up into the fabric of the global economy, putting us at the precipice of operationalizing one possible Structural One Health. In recent research, Bergmann et al. (in preparation) have been examining the ways processes of globalization contribute to the emergence and persistence of diseases. In searching for the covariates to be inputted into a niche analysis of disease presence, Bergmann et al. are considering the potential role for local ecological variables such as land cover, host species distributions, and climate, but in addition social variables and human—ecological interaction terms. Beyond those potentially causal variables that are easily available in both practical and conceptual terms, such as population density rasters, the team is exploring the roles played by global interconnections. Such a relational approach is ubiquitous within the contemporary social sciences, but still as yet underexamined within One Health.

Bergmann et al. are including candidate covariates that for the first time quantify the extent to which local agroecological landscapes such as fields and forests—and the natural and cultural processes that crisscross them—have been globalized. Landscapes are entrained by transnational commodity chains and circuits of capital, including financial and productive circuits, with critical local effects. Harvey (1982/2006) argued even globalized markets introduce anisotropic distributions to labor, exchange and production. Indeed, as economic geographers since Karl Marx (1885/1993) have noted, such polarities, dynamic in time and space, drive innovations in capital's geographic deployment, serving as sources of new profit in inherently stagnating markets (Sheppard and Barnes, 1990; Magdoff and Foster, 2014). By shifts in technology, transport, fixed capital, land price, effective demand, locational competition, credit availability, management, labor discipline and state investment, a locale may suddenly become transiently conducive to cheap livestock production and advantageous exchange (Harvey, 1982/2006; Leonard, 2014). The new geography of production and the 'spatial fixes' companies undertake link intensive transformations of human—environmental relations to extensive global trade, with, Bergmann's group hypothesizes, statistically significant impacts upon pathogen evolution and spread. As in the historical precedents we explored in the first section, changing husbandry's economic geography should reset the mix of ecological opportunities and evolutionary selection pressures acting on infections.

By reconstructing Global Trade Analysis Project 7 data (Narayanan and Walmsely, 2008) commonly used to model all the connections of the global economy for the purposes of trade negotiations, Bergmann and Holmberg (in preparation) have estimated capital's agroecological footprints (Fig. 3). Products from globalized croplands, forests, or pastures eventually contribute to consumption or capital accumulation in other countries (Bergmann, 2013b). Other landscapes are enmeshed primarily within local circuits of production and exchange. Bergmann (2013b) extends beyond characterizing landscapes that directly produce traditional agricultural exports to identifying the forests and fields that are part of commodity webs supporting export-

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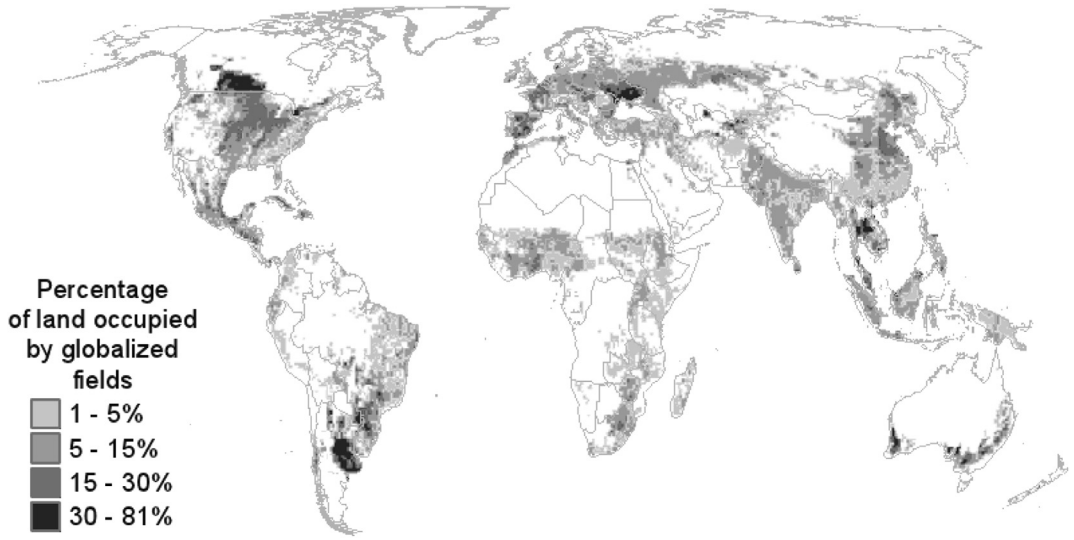

Fig. 3. Globalization of croplands, 2004. Percentage of landscape area occupied by croplands whose products are incorporated as part of commodity chains (agricultural or otherwise) whose first consumers are located internationally (calculations by Bergmann and Holmberg; *c.f.* Bergmann, 2013a, Bergmann, 2013b).

oriented development producing goods or services for overseas benefit. Bergmann further differentiates between foreign consumption/accumulation of 'direct' agricultural goods (*e.g.,* fruit or grain); refined or processed agricultural goods (cloth, peanut butter, meat products); manufactured goods (electronics and vehicles); and services (air transport, insurance, education).

How are half-degree rasters of such moments in global circuits of capital to be connected to emergent disease? Are any of these landscapes better related to particular geo-coded outbreaks, as captured, for instance, by FAO's EMPRES Global Animal Disease Information System (EMPRES-i), than simple maps of global land use that fail to differentiate by positionality with respect to circuits of capital? One may wish to control for a variety of other variables, but regardless, this particular Structural One Health seeks more than mere spatial correlations between land uses and particular diseases, as we previously noted Robinson et al. (2014) have called into question. It should be able to differentiate, on the one hand, between the proximity of outbreaks to transnational capital as opposed to transnational consumers/laborers and to local livelihoods or local capital. On the other hand, such an approach should be able to help researchers develop a sense for whether diseases that emerge in economic/agroecological landscapes are connected to export-oriented agriculture, manufacturing, or even services. With the synergistic nature of disease emergence, more-than-local and nonlinear approaches to the empirical study of human-environment processes within One Health are increasingly feasible and fundamental to the future of the field.

For instance, Wallace et al. (in preparation) are using Bergmann's circuits of capital in a statistical phylogeography of Asian H7 and N9 isolates dating back to the 1980s to identify the sociospatial pathways by which the new avian influenza A (H7N9), first detected around Shanghai in 2013, emerged. The team is developing a niche analysis on the MaxEnt (Elith, 2011) and Boosted Regression Trees (Van Boeckel et al., 2012b) models to test which of a series of geo-coded social and environmental covariates, including connections to said circuits of capital, characterizes the isolate locales and the localities visited by the virus as inferred by the phylogeographies. The scale and mechanisms of H7N9's emergence are to be arrived at by an automated (if confidence-bounded) exploration of the multidimensional data space over which viral genetics, locales, and the socioecological matrix are related, rather than out of a strict set of *a priori* (and ultimately arbitrary) categories.

Caveats around such work abound—especially around data resolution and availability—but in effect researchers should be able to assign a matrix of indices of export to each disease or strain included in such analysis. Some pathogens, such as some of the avian influenzas, may emerge by local or cross-sectoral agricultural practices (*i.e.*, in a mosaic landscape of backyard and intensive husbandry) (Martin et al., 2011). Others, such as PRRS and PEDv, may be more or even exclusively globalized in its agroecologies, perhaps by some combination directly related to agriculture and indirectly to manufactured goods and services as far afield as, for instance, computers and insurance. Still others may take on multiple identities across time and space. In other words, for the first time epidemiologists may be able to statistically test for, numerically weigh, and qualify the world's 'agribusiness diseases,' which until now have been characterized largely descriptively. More generally, the new approach should offer a novel, intuitive and rigorous means of coding the economic character of emergent diseases.

The One Health perspective is reintroducing scientific investigation to the questions its constituent disciplines have long avoided as a matter of epistemological course. On the other hand, the approach's present episodic abstraction appears overdetermined in time and place while maneuvering causality away from systemic sources. The Structural One Health we introduce here aims to place all sources of cause and effect atop the metaphorical table, including episodic circumstances, foundational and historical contexts, and scientific practice itself. Other structural and post-structural approaches to multispecies health are also open to exploration.

Ethics approval

No data were collected from human subjects for this submission.

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