Historical Literature Related to Zoonoses and Pandemics

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Abstract: The coronavirus (SARS-CoV-2) is the latest but not the first deadly pathogen to jump from animals to humans. The history of pandemics is replete with such events. The convergence of animal health, human health, and ecosystem health is a twenty-first century reality, as human activities that drive climate change also contribute to pandemic risk. Understanding the past and future of zoonotic diseases requires new models in the way we research human-animal-environment interconnections. This bibliographic essay discusses the historical development of these zoonotic diseases and incorporates sources from the history of science and medicine, environmental science, animal science, disease ecology, politics, and anthropology. Contributing to deeper understandings of zoonotic diseases, historians and anthropologists have viewed pandemics as social and biological phenomena. However, viewpoints differ whether scholars routinely examine disease links between animals and humans. These links include the ecological aspects of infectious diseases' history and the role of wildlife as vectors of zoonotic disease. In addition, challenges persist in integrating social sciences and humanities, the environmental sector, and scientific research. Ideally, historiographies of zoonotic diseases would include societies' responses and the social, cultural, political, economic, and ecological contexts. This bibliographic essay assembles resources that would benefit such an integrated approach.

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The coronavirus (SARS-CoV-2) is the latest but not the first deadly pathogen to jump from animals to humans. The history of pandemics is replete with such events. This bibliographic essay will discuss the historical development of these "zoonotic" diseases. It will contribute to an integrated historiography by incorporating sources from the history of science and medicine, environmental science, animal science, disease ecology, politics, and anthropology.

After a brief overview of Zoonotic Disease Science, the essay will treat animal infections at the human-animal interface. A section on disease entanglements will follow, treating the human-animal-environment dimensions of zoonotic diseases. The next section will treat how historians have engaged with biology, animal studies, social sciences, and anthropology. There is then a discussion of well-known historical zoonoses, including the Black Death, HIV-AIDS, avian influenza, COVID-19, and others. The last section will discuss One Health, as the integrated study of emerging diseases.

ZOONOTIC DISEASES: OVERVIEW OF THE SCIENCE

A zoonosis is an infectious disease caused by a pathogen (a bacterium, virus, parasite, or prion) that jumped from an animal to a human or from an insect to a human (vector-borne zoonoses). Researchers report that zoonoses contribute to an estimated 75% of *new* infectious diseases for humans. Examples include bacterial zoonoses (anthrax, salmonellosis, tuberculosis, Lyme disease, plague); viral zoonoses (rabies, HIV-AIDS, Ebola, avian influenza, SARS, MERS, COVID-19); and parasitic zoonoses (giardiasis, malaria). Zoonotic diseases transmit naturally from animals to humans. For example, birds, bats, and rats regularly spread zoonotic pathogens, as do various insects.[2]

According to disease ecologists, most human pathogens originated with animals. Genomic studies reveal that measles, smallpox, influenza, HIV-AIDS, diphtheria, and others came from animals. For example, measles emerged from *rinderpest* ages ago, when domestication of wildlife led to a spillover of their pathogens to humans.[3] After passing from animals to humans, zoonoses can be transmitted from human-to-human, which can result in a pandemic. While it is rare for a zoonotic disease to develop into a pandemic, it is a dramatic event when it does occur.

Zoonotic diseases have become more common since the 1950s, and especially since the 1970s. This increase results from human population growth, including encroachment into wild animal habitats, deforestation, industrial farm production, climate change, and global travel and

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[2] Judith Recht, Verena J. Schuenemann, and Marcelo R. Sánchez-Villagra, "Host Diversity and Origin of Zoonoses: The Ancient and the New," *Animals* 10, no. 9 (September 17, 2020): 1672; Anthony S. Fauci, "Emerging and Reemerging Infectious Diseases: The Perpetual Challenge," *Academic Medicine* 80, no. 12 (2005); Joann Colville and David Lee Berryhill, *Handbook of Zoonoses: Identification and Prevention* (St. Louis, MO: Mosby/Elsevier Inc, 2007); L. H. Taylor, S. M. Latham, and M. E. J. Woolhouse, "Risk Factors for Human Disease Emergence," *Philosophical Transactions of the Royal Society B: Biological Sciences* 356, no. 1411 (July 2001): 983–89; Tanvir Rahman et al., "Zoonotic Diseases: Etiology, Impact, and Control," *Microorganisms* 8, no. 9 (September 12, 2020): 1405.

[3] J. O. Lloyd-Smith et al., "Epidemic Dynamics at the Human-Animal Interface," *Science* 326, no. 5958 (December 2009): 1362–67; Richard S. Ostfeld, "Disease Ecology," in *Ecology*, by Richard S. Ostfeld (Oxford: Oxford University Press, 2015); Ariane Düx et al., "Measles Virus and Rinderpest Virus Divergence Dated to the Sixth Century BCE," *Science* 368, no. 6497 (June 19, 2020): 1367–701.

trade. The increasing domination of the ecosystem by humans has accelerated the host-switching of animal pathogens, particularly viruses.[4] However, scholars disagree about how complex social, microbial, and environmental factors affect pandemic risk. In a further complication, evidence reveals that humans can also infect animals, a "reverse zoonosis," with unpredictable outcomes across species.[5]

ANIMAL INFECTIONS AT THE HUMAN-ANIMAL INTERFACE

According to disease ecologists, the first zoonotic pathogens—measles and smallpox—emerged in humans between 200 BCE and 300 CE. In the fourteenth century, the Black Death entered Europe, following the expansion of global trade and transportation networks and the beginning of European colonization. In the fifteenth and sixteenth centuries, European colonizers brought smallpox to the Americas. In more recent times, air travel and general globalization has been accompanied by the development of pandemic influenza, HIV/AIDS, and the current coronavirus pandemic. Science journalist David Quammen describes zoonotic diseases through case studies that depict how, where, and why zoonotic pathogens spill over from animals.[6]

The links between human and animal diseases have been of interest throughout the early modern and modern periods. Historian Frank Snowden offers a valuable perspective on societies' vulnerabilities to pandemics, beginning with the Black Death. Linda Kalof and Brigitte Pohl-Resl's multi-volume project on the history of human-animal relations encompasses 4500 years of human-animal interaction. Reviewing the animal origins of human diseases, Anne Hardy tracked scientific milestones for diseases among animals and humans. Likewise, E. Torrey and Robert Yolken described the history of zoonotic diseases and the interconnectedness between human and animal pathogens within their shared environments.

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[4] United Nations Environmental Program (UNEP), "Preventing the Next Pandemic: Zoonotic Diseases and How to Break the Chain of Transmission," 2020; David A Relman et al., eds., *Microbial Evolution and Co-Adaptation*, Forum on Microbial Threats (Washington D.C.: The National Academies Press, 2009); P. Daszak, "Emerging Infectious Diseases of Wildlife—Threats to Biodiversity and Human Health," *Science* 287, no. 5452 (January 21, 2000): 443–49; Joan L. Aron and Jonathan A. Patz, eds., *Ecosystem Change and Public Health: A Global Perspective* (Baltimore: Johns Hopkins University Press, 2001); Tony McMichael, *Human Frontiers, Environments and Disease: Past Patterns, Uncertain Futures* (Cambridge; New York: Cambridge University Press, 2001); Peter Daszak, "Can We Predict Future Trends in Disease Emergence?," in *Microbial Evolution and Co-Adaptation, Workshop Summary*, Forum on Microbial Threats (Washington DC: National Academies Press, 2009); Carlos Santana, "COVID-19, Other Zoonotic Diseases and Wildlife Conservation," *History and Philosophy of the Life Sciences* 42, no. 4 (December 2020): 45.

[5] Bas B. Oude Munnink et al., "Transmission of SARS-CoV-2 on Mink Farms between Humans and Mink and Back to Humans," *Science* 371, no. 6525 (January 8, 2021): 172–77; Robin A. Weiss and Neeraja Sankaran, "Emergence of Epidemic Diseases: Zoonoses and Other Origins," *Faculty Reviews* 11 (January 18, 2022); Anita Guerrini, "Animals, Vaccines, and COVID-19," *Endeavour* 45, no. 3 (September 2021).

[6] Daszak, "Can We Predict Future Trends in Disease Emergence?"; Emory University, "Zoonotic Diseases: How Pathogens Jump Species," *Emory Health Digest,* 2020, http://news.emory.edu/features/2020/06/ehd-zoonotic-diseases/; Andrew P. Dobson and E. Robin Carper, "Infectious Diseases and Human Population History," *BioScience* 46, no. 2 (February 1996): 115–26; David Quammen, *Spillover: Animal Infections and the Next Human Pandemic* (New York: W.W. Norton & Co., 2012).

Finally, using texts written between 1558 and 1649, Erica Fudge has explored relationships among people and animals.[7]

Scholars have also explored the history of animals within the context of modern medicine. Angela Woods et al. argued that animals played three distinct roles in human and veterinary history: experimental material, disease victims, and disease transmitters. Regarding animal experimentation, Michael Worboys pointed out that pathology stimulated a new understanding of diseases between animals and humans, particularly for anthrax and tuberculosis. Likewise, Robert Kirk examined the history of animal-human experimentation. Anita Guerrini surveyed experimental practices in antiquity and illuminated the links between anatomy and natural history in seventeenth-century France. Finally, addressing the history of animal use in biomedical research, Nuno Franco focused on societal effects from antiquity to today.[8]

Creating a twenty-first century look at animal ecology, Angela Woods et al. placed animals at the center of modern medicine, recognizing deep zoological roots in human medicine. Similarly, Susan Nance investigated animal-centered histories to gain fresh perspectives on what constituted medicine throughout history, and Angela Cassidy examined the history of animals through the traces they left on medical-historical records.[9] Addressing the

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[7] E. Fuller Torrey and Robert H Yolken, *Beasts of the Earth: Animals, Humans, and Disease* (New Brunswick, NJ: Rutgers University Press, 2005); Anne Hardy, "Animals, Disease, and Man: Making Connections," *Perspectives in Biology and Medicine* 46, no. 2 (2003): 200–215; Erica Fudge, "Ruminations I: The History of Animals," in *Representing Animals*, ed. Nigel Rothfels, Theories of Contemporary Culture, v. 26 (Bloomington: Indiana University Press, 2002); Erica Fudge, *Perceiving Animals: Humans and Beasts in Early Modern English Culture*, (Urbana: University of Illinois Press, 2002); Frank M. Snowden, *Epidemics and Society: From the Black Death to the Present*, The Open Yale Courses Series (New Haven, CT: Yale University Press, 2019); Linda Kalof and Brigitte Pohl-Resl, eds., *A Cultural History of Animals*, English ed. (Oxford, UK; New York: Berg, 2007).

[8] Anita Guerrini, *Experimenting with Humans and Animals: From Galen to Animal Rights* (Baltimore: Johns Hopkins University Press, 2003); Nuno Franco, "Animal Experiments in Biomedical Research: A Historical Perspective," *Animals* 3, no. 1 (March 19, 2013): 238–73, https://doi.org/10.3390/ani3010238; Pratik Chakrabarti, "Beasts of Burden: Animals and Laboratory Research in Colonial India," *History of Science* 48, no. 2 (June 2010): 125–51, https://doi.org/10.1177/007327531004800201; Robert G. W. Kirk, "The Experimental Animals," in *The Routledge Companion to Animal-Human History* (London; New York: Routledge/Taylor & Francis Group, 2018); Michael Worboys, *Spreading Germs: Disease Theories and Medical Practice in Britain, 1865-1900* (Cambridge, UK: Cambridge University Press, 2006); Anita Guerrini, *The Courtiers' Anatomists: Animals and Humans in Louis XIV's Paris* (Chicago: University of Chicago Press, 2015); Abigail Woods et al., *Animals and the Shaping of Modern Medicine: One Health and Its Histories*, 1st ed. 2018, Medicine and Biomedical Sciences in Modern History (Cham: Springer International Publishing: Imprint: Palgrave Macmillan, 2018).

[9] Susan Nance, ed., *The Historical Animal*, (Syracuse, NY : Syracuse University Press, 2015); Angela Cassidy, "One Medicine: Advocating (Inter)Disciplinarity at the Interfaces of Animal Health, Human Health, and the Environment," in *Investigating Interdisciplinary Collaboration: Theory and Practice across Disciplines*, eds. S. Frickel and B. Prainsack (Washington DC: National Academies Press, 2016); Angela Cassidy et al., "Animal Roles and Traces in the

interdisciplinarity of human-animal studies, the collected essays of Hilda Kean and Philip Howell surveyed the challenges posed by the historical studies of animals. Contributions from artists and scholars in human-animal studies appeared in the edited collection of Susan McHugh and Garry Marvin.[10]

Veterinarians have been an integral part of the history of human-animal relationships. In her exploration of the rise of veterinary medicine in America, Susan Jones reviews conflicting perspectives on domesticated animals. Karen Brown and Daniel Gilfoyle's essay collection treats veterinary science from the eighteenth century to the present. They discuss livestock economies and veterinary medicine, using case studies of animal diseases from Europe, North America, Africa, Asia, and Australasia. Tatsuya Mitsuda examines German veterinary medicine and finds that veterinarians often referred to experts in medicine, food, agriculture, and the military. Similarly, Kirk and Worboys discuss animals within human medicine, including human medicine's link to veterinary medicine. Frédéric Keck and Christos Lynteris highlight how human and veterinary medicine have become intertwined. Rabies, for example, has been a subject of study by both medical historians and animal-human historians.[11]

History of Medicine, *c.* 1880–1980," *BJHS Themes* 2 (2017): 11–33; Abigail Woods et al., *Animals and the Shaping of Modern Medicine*.

[10] Hilda Kean and Philip Howell, eds., *Routledge Companion to Animal-Human History* (London; New York: Routledge/Taylor & Francis Group, 2018); Louise Hill Curth, *The Care of Brute Beasts: A Social and Cultural Study of Veterinary Medicine in Early Modern England*, in History of Science and Medicine Library, v. 14 (Leiden; Boston: Brill, 2010); Susan McHugh and Garry Marvin, *Routledge Handbook of Human-Animal Studies* (London; New York: Routledge Taylor & Francis Group, 2019); Harriet Ritvo, "Animal Planet," *Environmental History* 9, no. 2 (April 2004): 204; E. Benson, "Animal Writes: Historiography, Disciplinarity, and the Animal Trace Meaning," in *Making Animal Meaning.*, ed. Linda Kalof and Georgina M. Montgomery (East Lansing; Chicago: Michigan State University Press ; Chicago Distribution Center [distributor, 2012); Hilda Kean, "Challenges for Historians Writing Animal–Human History: What Is Really Enough?," *Anthrozoös* 25, no. sup1 (August 2012): s57–72; Anita Guerrini, "Animals and Ecological Science," in *The Oxford Handbook of Animal Studies*, ed. Linda Kalof (Oxford: Oxford University Press, 2017), 488–505; Donna Jeanne Haraway, *When Species Meet*, Posthumanities 3 (Minneapolis: University of Minnesota Press, 2008); Dan Vandersommers, "The 'Animal Turn in History,'" *Perspectives on History (AHA)*, (November 2016).

[11] Susan D. Jones, *Valuing Animals: Veterinarians and Their Patients in Modern America*, Animals, History, Culture (Baltimore: Johns Hopkins University Press, 2003); Karen Brown and Daniel Gilfoyle, eds., *Healing the Herds: Disease, Livestock Economies, and the Globalization of Veterinary Medicine*, Ohio University Press Series in Ecology and History (Athens: OH University Press, 2010); Tatsuya Mitsuda, "Entangled Histories: German Veterinary Medicine, *c.* 1770–1900," *Medical History* 61, no. 1 (January 2017): 25–47; Robert G. W. Kirk and Michael Worboys, *Medicine and Species: One Medicine, One History?*, ed. Mark Jackson, vol. 1 (Oxford: Oxford University Press, 2012); Frédéric Keck and Christos Lynteris, "Zoonosis," *Medicine Anthropology Theory* 5, no. 3 (June 25, 2018); Neil Pemberton and Michael Worboys, *Mad Dogs and Englishmen: Rabies in Britain, 1830 - 2000*, Science, Technology and Medicine in Modern History (Basingstoke: Palgrave Macmillan, 2007); Karen Brown, "Environmental and Veterinary History—Some Themes and Suggested Ways Forward," *Environment and History* 20, no. 4 (November 1, 2014): 547–59.

The nineteenth century was a turning point in our understanding of zoonotic diseases, for at that time bacteriological studies confirmed common microbial disease causes in humans and livestock. Rudolph Virchow studied such diseases in nineteenth-century Europe. A pioneer of pathology and public health, Virchow coined the term "zoonosis" in 1855. He recognized that most human diseases came from domestic animals, poultry, and livestock, and highlighted links between human and veterinary medicine. Anne Hardy and Mark Jackson have explored how rail and steamship transportation increased opportunities for animal disease transmission. According to Monica Green, the most successful zoonotic pathogens in history traveled through human trade and transportation networks.[12]

Veterinarian Calvin Schwabe writes about nineteenth-century scientists who worked with both human and non-human animals and advanced the study of zoonoses. These researchers included Louis Pasteur, who created the first vaccine against rabies, which is a zoonotic disease. Robert Koch discovered the bacterial zoonosis leading to human tuberculosis and outlined the animal-to-animal transmission of disease. William Osler taught both medical and veterinary students. Theobald Smith exposed ticks as vectors of cattle disease and recognized the relationship between bovine and human tuberculosis. John McFadyean founded veterinary pathology. And, of course, there is also Rudolf Virchow.[13]

Livestock diseases prompted historians to explore diseases at the human-animal interface. For example, according to Michael Bresalier, livestock diseases negatively impacted humans through poor nutrition, since sick animals could not produce meat and milk for consumption. Similarly, Angela Cassidy explored the relationships between bovine and human tuberculosis throughout human-animal history, while Susan Jones analyzed bovine tuberculosis control measures before World War I.[14]

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[12] Lise Wilkinson, *Animals and Disease: An Introduction to the History of Comparative Medicine* (Cambridge, UK; New York: Cambridge University Press, 2005); Anne Hardy, "Animals, Disease, and Man"; Mark Jackson, ed., *The Routledge History of Disease*, The Routledge Histories (London; New York: Routledge, Taylor & Francis Group, 2017); Corrie Brown, "Virchow Revisited: Emerging Zoonoses," *ASM News* (American Society for Microbiology) 69, no. 10 (2003): 493–97; Monica H. Green, "Emerging Diseases, Re-emerging Histories," *Centaurus* 62, no. 2 (May 2020): 234–47; Karen Brown, "Environmental and Veterinary History—Some Themes and Suggested Ways Forward"; Mark Harrison, *Contagion: How Commerce Has Spread Disease* (New Haven: Yale University Press, 2012); Darryl Stellmach et al., "Interdisciplinary Health Research," in *One Planet, One Health*, ed. Merrilyn Walton (Sydney: Sydney University Press, 2019).

[13] Calvin W. Schwabe, *Veterinary Medicine and Human Health*, (Baltimore: Williams & Wilkins, 1984); Steve M. Blevins and Michael S. Bronze, "Robert Koch and the 'Golden Age' of Bacteriology," *International Journal of Infectious Diseases* 14, no. 9 (September 2010): e744–51; Christoph Gradmann, "Robert Koch and the White Death: From Tuberculosis to Tuberculin," *Microbes and Infection* 8, no. 1 (January 2006): 294–301; Pierre-Olivier Méthot, "Why Do Parasites Harm Their Host? On the Origin and Legacy of Theobald Smith's 'Law of Declining Virulence'—1900-1980," *History and Philosophy of the Life Sciences* 34, no. 4 (2012): 561–601.

[14] Keir Waddington, "To Stamp Out 'So Terrible a Malady': Bovine Tuberculosis and Tuberculin Testing in Britain, 1890–1939," *Medical History* 48, no. 1 (January 1, 2004): 29–48; Keir Waddington, "The Science of Cows: Tuberculosis, Research and the State in the United Kingdom, 1890–1914," *History of Science* 39, no. 3 (September 2001): 355–81; Keir Waddington, *The Bovine Scourge: Meat, Tuberculosis and Public Health, 1850-1914*

The deadly cattle plague, known as rinderpest, is an important livestock disease. Rinderpest does not transmit to humans (unlike rabies, anthrax, and bovine tuberculosis), but it does create economic and social burdens, including human poverty and hunger. Karen Brown's veterinary and environmental history shows that efforts to control infections such as rinderpest played a role in the development of regulatory power in European colonial states. Amanda Kay McVety has examined the international efforts to eradicate rinderpest, beginning in the 1940s and ending with its eradication in 2011.[15]

Susan Jones discusses Charles Elton's contributions to animal ecology during the 1920s-1930s. After World War II, animals with zoonotic diseases were medically treated to reduce the transmission of these diseases. At the same time, economic pressures encouraged larger farms to house more animals. Livestock crowding, in turn, led to new zoonotic diseases. Bryony Jones et al. examined the effects of agricultural intensification on the risks of zoonotic pathogens among wildlife and livestock. Richard Tucker highlighted the effects of agricultural intensification in the tropics through case studies of six major crops: sugar, bananas, coffee, rubber, beef, and timber.[16]

Sociologists Carrie Friese and Nathalie Nuyts have used a bibliometric analysis to measure the sharp rise in research involving animals in public health. In 2019, Hannah Brown and Alex

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(Woodbridge, UK; Rochester, NY: Boydell Press, 2006); Peter Koolmees, "Bovine Brucellosis and Post-War Dutch Veterinary Medicine," in *Geschichte Der Gynäkologie Und Andrologie Der Haustiere*, ed. J. Schäffer (Geissen, 2008); Hardy, "Animals, Disease, and Man"; Susan D. Jones, "Mapping a Zoonotic Disease: Anglo-American Efforts to Control Bovine Tuberculosis before World War I," *Osiris* 19 (January 2004): 133–48; Michael Bresalier, "From Healthy Cows to Healthy Humans: Integrated Approaches to World Hunger, c.1930–1965," in *Animals and the Shaping of Modern Medicine*, by Abigail Woods et al. (Cham: Springer International Publishing, 2018), 119–60; Brown and Gilfoyle, *Healing the Herds*; Fleur Anne Haalboom, "Negotiating Zoonoses: Dealings with Infectious Diseases Shared by Humans and Livestock in the Netherlands (1898-2001)" (Utrecht: University of Utrecht, 2017); Angela Cassidy, *Vermin, Victims and Disease* (Cham: Springer International Publishing, 2019); Peter Koolmees, "Veterinary Inspection and Food Hygiene in the Twentieth Century," in *Food, Science, Policy and Regulation in the Twentieth Century: International.* (London: Routledge, 2016).

[15] Amanda Kay McVety, *The Rinderpest Campaigns: A Virus, Its Vaccines, and Global Development in the Twentieth Century*, in Global and International History (Cambridge, UK; New York: Cambridge University Press, 2018); Karen Brown, "Environmental and Veterinary History;" Abigail Woods, "Patterns of Animal Disease," in *The Routledge History of Disease*, ed. Mark Jackson, 2019; T. M. Romano, "The Cattle Plague of 1865 and the Reception of 'The Germ Theory' in Mid-Victorian Britain," *Journal of the History of Medicine and Allied Sciences* 52, no. 1 (January 1, 1997): 51–80.

[16] Susan D. Jones, "Population Cycles, Disease, and Networks of Ecological Knowledge," *Journal of the History of Biology* 50, no. 2 (May 2017): 357–91; Charles Elton, *Animal Ecology* (Chicago: University of Chicago Press, 1926); Bryony A. Jones et al., "Zoonosis Emergence Linked to Agricultural Intensification and Environmental Change," *Proceedings of the National Academy of Sciences* (May 13, 2013): 232-316; Richard P. Tucker, *Insatiable Appetite: The United States and the Ecological Degradation of the Tropical World, Concise* (Lanham, MD: Rowman & Littlefield Publishers, 2007); Antoine C. Dussault, "Neither Superorganisms nor Mere Species Aggregates: Charles Elton's Sociological Analogies and His Moderate Holism about Ecological Communities," *History and Philosophy of the Life Sciences* 42, no. 2 (June 2020): 25.

Nading explored human-animal entanglement, anthropogenic changes, and the need to move beyond traditional disciplinary boundaries. According to Susan Nance, zoonotic disease calls for multi-disciplinary collaboration or what she calls "radical interdisciplinarity."[17] However, this interdisciplinary approach to human-animal histories is problematical. Anne Hardy noted that scientists treat human and animal health as independent disciplines, and often ignore the links between animal and human diseases. According to Brown, scholars have neglected wildlife as vectors of disease. Robert Kirk and Michael Worboys noted that medical and veterinary historians have human-centered perspectives that are quite different from animal-focused histories. Another barrier, according to Woods et al., is that collaborative team approaches in history are infrequent.[18]

DISEASE ENTANGLEMENTS: HUMAN-ANIMAL-ENVIRONMENT

Disease ecology, a highly interdisciplinary field, deals with microbes, host animals, and landscape-scale disease effects. As an integral part of the ecology, zoonotic pathogens are more likely to emerge when humans alter the host animal's ecosystem. Historian Mirko Grmek contributed to the development of disease ecology with foundational essays about the interconnections of diseases, societies, and medical theories. Nevertheless, according to Warwick Anderson, historians have neglected the ecological factors to emphasize the development of laboratory models, microbe hunting, and magic bullet treatments.[19] Only in the

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[17] Carrie Friese and Nathalie Nuyts, "Posthumanist Critique and Human Health: How Nonhumans (Could) Figure in Public Health Research," *Critical Public Health* 27, no. 3 (May 27, 2017): 303–13; Hannah Brown and Alex M. Nading, "Introduction: Human Animal Health in Medical Anthropology," *Medical Anthropology Quarterly* 33, no. 1 (March 2019): 5–23; Nance, *The Historical Animal:* 3, 8.

[18] Hardy, "Animals, Disease, and Man": 200-215; Brown, "Environmental and Veterinary History—Some Themes and Suggested Ways Forward": 549-59; Christos Lynteris, "Introduction: Infectious Animals and Epidemic Blame," in *Framing Animals as Epidemic Villains*, ed. Christos Lynteris (Cham: Springer International Publishing, 2019), 1–25; Kenneth Shapiro, "Human-Animal Studies: Remembering the Past, Celebrating the Present, Troubling the Future," *Society & Animals* 28, no. 7 (November 25, 2020): 797–833; Martin Enserink, "Medicine: Initiative Aims to Merge Animal and Human Health Science to Benefit Both," *Science*, no. 316 (2007); Kirk and Worboys, *Medicine and Species*: 561-77; Woods et al., *Animals and the Shaping of Modern Medicine* (London: Palgrave Macmillan, 2017).

[19] W. Anderson, "Natural Histories of Infectious Disease: Ecological Vision in Twentieth-Century Biomedical Science," in *Osiris: Landscapes of Exposure*, ed. Gregg Mitman, Michelle Murphy, and Christopher Sellers, vol. 19, 2004: 39–61; Mark Honigsbaum, "'Tipping the Balance': Karl Friedrich Meyer, Latent Infections, and the Birth of Modern Ideas of Disease Ecology," *Journal of the History of Biology* 49, no. 2 (April 2016): 261–309; Green, "Emerging Diseases, Re-emerging Histories": 234-47; Honigsbaum and Méthot, "Introduction: Microbes, Networks, Knowledge. *History and Philosophy of the Life Sciences* 42, no. 3 (September 2020): 28; Joshua Lederberg, Robert E. Shope, and Stanley Oaks. *Emerging Infections: Microbial Threats to Health in the United States*. Washington DC: National Academies Press, 1992; Pierre-Olivier Méthot and Bernardino Fantini, "Medicine and Ecology: Historical and Critical Perspectives on the Concept of 'Emerging Disease,'" *Archives Internationales d'Histoire des Sciences* 64, no. 172–173 (June 2014): 213–30; Jon Arrizabalaga, "At the Intersection of Medical Geography and Disease Ecology: Mirko Grmek, Jacques May and the Concept of Pathocenosis,"

last few years has a team of virologists and microbiologists created an annotated bibliography covering zoonotic viruses and their interactions with the environment and animal hosts.[20]

In a collection of essays, Mark Honigsbaum and Pierre-Oliver Méthot review the global history of disease ecology in the past century. Equally important, Flavio D'Abramo and Sybille Neumeyer explore how industrial and technological advancements impact human societies and result in significant changes in the earth's microbial and biological levels. Likewise, Honigsbaum links microbial behavior to broader bio-ecological, environmental, and social factors that impact host-pathogen interactions. This theme is also explored by Méthot and Rachel Dentinger.[21]

During the 1930s, ecologist Aldo Leopold argued that wildlife disease is an ecological issue influenced by human activities. Two other disease ecologists of this era, MacFarlane Burnet and René Dubos focused on the complex interplay of disease, host animals, and their environment. Nevertheless, by the 1960s, there was a trend away from disease ecology, as funds shifted to dissecting biological systems into their constituent parts. Virologist Joshua Lederberg opposed this trend, urging fellow scientists to replace the metaphor of "war on disease" with an approach that included the pathogen, animal host, and environment. Increasing confidence in antibiotics and vaccines contributed to the neglect of an ecological understanding of microbes and disease. In 1967, the US Surgeon General recommended closing the book on infectious diseases to focus on chronic human diseases. Some scientists made incorrect assumptions that the future of infectious diseases in humans would be dull. [22]

History and Philosophy of the Life Sciences 40, no. 4 (December 2018): 71; Mirko D. Grmek, *Pathological Realities: Essays on Disease, Experiments, and History*, edited by Pierre-Olivier Méthot. 1st ed. (New York: Fordham University Press, 2018); Linda Lorraine Nash, *Inescapable Ecologies: A History of Environment, Disease, and Knowledge* (Berkeley: University of California Press, 2006).

[20] Vincent Munster, Seth Judson, and Michael Letko, "Ecology of Emerging Zoonotic Viruses" (Oxford: Oxford University Press, February 22, 2018); A. Alonso Aguirre, ed., *Conservation Medicine: Ecological Health in Practice* (Oxford; New York: Oxford University Press, 2002); Alonso Aguirre, "Changing Patterns of Emerging Zoonotic Diseases in Wildlife, Domestic Animals, and Humans Linked to Biodiversity Loss and Globalization," *ILAR Journal* 58, no. 3 (December 15, 2017): 315–18.

[21] Donald Worster, *Nature's Economy: A History of Ecological Ideas* (Cambridge, UK: Cambridge University Press, 1994); Pierre-Olivier Méthot and Rachel Mason Dentinger, "Ecology and Infection: Studying Host-Parasite Interactions at the Interface of Biology and Medicine," *Journal of the History of Biology* 49, no. 2 (April 2016): 231–40; Flavio D'Abramo and Sybille Neumeyer, "A Historical and Political Epistemology of Microbes," *Centaurus* 62, no. 2 (May 2020): 321–30; Honigsbaum and Méthot, "Introduction: Microbes, Networks, Knowledge,": 28.

[22] Aldo Leopold, *Game Management* (Madison, WI: University of Wisconsin Press, 1986); René Dubos, *Mirage of Health : Utopias, Progress and Biological Change [1959]* (New Brunswick: Rutgers University Press, 1987); Mark Honigsbaum, "René Dubos, Tuberculosis, and the 'Ecological Facets of Virulence'," *History and Philosophy of the Life Sciences* 39, no. 3 (September 2017): 15; F. M Burnet and David O White, *Natural History of Infectious Disease* (Cambrdige, UK: Cambridge : University Press, 1972); Joshua Lederberg, "Infectious History," *Science* 288, no. 5464 (April 2000): 287–93; Honigsbaum and Méthot, "Introduction: Microbes, Networks, Knowledge."

In recent years, disease ecology has become more prominent as an explanation for zoonoses. These analyses include the impact of climate change on human health. Nevertheless, Honigsbaum et al. claimed that contemporary historiography does not explain when and how disease ecology entered the medical mainstream before the 1990s. According to much published science and historical analysis, climate change expands the risk for zoonoses. Noami Oreskes and Erik Conway provide a compelling look at the political contexts of climate change. Harvard University and the Planetary Health Alliance (PHA) have collaborated to understand the health impacts of an accelerating global environmental change. Animal health researchers have argued that exploring disease across species might better explain the role of climate than focusing on individual diseases.[23]

In 2020, the *Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services* (IPBES) addressed the links between environmental degradation, the loss of biodiversity, and the increasing risk of pandemics. Their conclusion agrees with the assessment of the United Nations Environmental Program: the loss of biodiversity has paved the way for the current pandemic era. Environmental historian Gregg Mitman argues that our current pandemic is an ecological crisis, and that our current understanding often underplays the effects of economic and racial injustices underlying this pandemic.[24]

HISTORY MEETS BIOLOGY, ANIMAL SCIENCE, AND SOCIAL SCIENCES

In a 2014 roundtable entitled "History Meets Biology," the American Historical Association addressed how historians can approach the co-evolution of humans with other species. Mark

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[23] Jonathan A. Patz et al., "Impact of Regional Climate Change on Human Health," *Nature* 438, no. 7066 (November 2005): 310–17; Paul R. Epstein, "Climate Change and Infectious Disease: Stormy Weather Ahead?," *Epidemiology* 13, no. 4 (July 2002): 373–75; C. D. Harvell, "Climate Warming and Disease Risks for Terrestrial and Marine Biota," *Science* 296, no. 5576 (June 2002): 2158–62; UNEP, "Preventing the Next Pandemic: Zoonotic Diseases and How to Break the Chain of Transmission"; Claire Heffernan, "Climate Change and Infectious Disease: Time for a New Normal?," *The Lancet Infectious Diseases* 15, no. 2 (February 2015): 143–44; Samuel Myers and Howard Frumkin, *Planetary Health: Protecting Nature to Protect Ourselves* (Washington DC: Island Press, 2020); Joshua P. Howe, ed., *Making Climate Change History: Documents from Global Warming's Past*, Weyerhaeuser Environmental Classics (Seattle: University of Washington Press, 2017); Spencer Weart, *The Discovery of Global Warming*, (Cambridge, MA: Harvard University Press, 2008); Naomi Oreskes and Erik M. Conway, *The Collapse of Western Civilization: A View from the Future* (New York: Columbia University Press, 2014).

[24] R. S. Ostfeld, "Biodiversity Loss and the Rise of Zoonotic Pathogens," *Clinical Microbiology and Infection: The Official Publication of the European Society of Clinical Microbiology and Infectious Diseases* 15 Suppl. 1 (January 2009): 40–43; UNEP, "Preventing the Next Pandemic: Zoonotic Diseases and How to Break the Chain of Transmission"; Jones et al., "Zoonosis Emergence Linked to Agricultural Intensification and Environmental Change"; Gregg Mitman, "In Search of Health: Landscape and Disease in American Environmental History," *Environmental History* 10, no. 2 (April 1, 2005): 184–210; Gregg Mitman, "The Unruliness of a Virus," in *Reflections: Environmental History in the Era of COVID-19*, vol. 25, Environmental History (Oxford University Press for the American Society of Environmental History, 2020); Intergovernmental Science-Policy Platform On Biodiversity And Ecosystem Services (IPBES), "Workshop Report on Biodiversity and Pandemics," (Zenodo, October 29, 2020).

Harrison suggested that a global perspective would best illuminate critical issues for historians of health, disease, and medicine. Similarly, Robert Kirk and Michael Worboys urged historians to reimagine the history of medicine as the history of interspecies interactions.[25]

Increasingly, historians have provided valuable models for an integrated study of disease. History is informing biology in the sense that historical analyses reveal diseases' social and economic frames. For example, Nükhet Varlık's collaborative work on plague included history, epidemiology, genomics, ecology, and bio-archaeology. Monica Green shows that molecular genetics has become yet another powerful tool for uncovering the histories of microbes.[26]

Historians have long examined the social contexts of infectious diseases. For example, Robert Peckham examined the entanglement of social, cultural, economic, and political contexts for infectious diseases across Asia. According to David Arnold, western medicine became a battleground between the colonized and the colonizers in nineteenth-century India. Warwick Anderson studied disease in the Philippines to reveal insights into the local social life, culture, and governance. Frédéric Keck documented how Asian states jointly created a system of warnings for impending epidemics. Finally, by examining the emergence of tropical medicine in France, Michael Osborne discusses the impact of new diseases on colonizers.[27]

The Anthropocene, which is the period when humanity began to have a dominant influence on the environment, has emerged as a major part of the new historical narrative. For example,

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[25] Kirk and Worboys, *Medicine and Species*; AHR Roundtable, "History Meets Biology," *American Historical Review*, December 2014; Mark Harrison, "A Global Perspective: Reframing the History of Health, Medicine, and Disease," *Bulletin of the History of Medicine* 89, no. 4 (2015): 639–89.

[26] Nükhet Varlik, *Plague and Empire in the Early Modern Mediterranean World: The Ottoman Experience, 1347–1600*, 1st ed. (Cambridge, UK: Cambridge University Press, 2015); Monica Green, "Genetics as a Historicist Discipline: A New Player in Disease History," *Perspectives on History*, (December 2014); Christos Lynteris, *Ethnographic Plague: Configuring Disease on the Chinese-Russian Frontier* (London: Palgrave Macmillan, 2016); Nükhet Varlık, "Rethinking the History of Plague in the Time of COVID-19," *Centaurus* 62, no. 2 (May 2020): 285–93.

[27] Frédéric Keck, "Asian Tigers and the Chinese Dragon: Competition and Collaboration between Sentinels of Pandemics from SARS to COVID-19," *Centaurus* 62, no. 2 (May 2020): 311–20; David Arnold, *Colonizing the Body: State Medicine and Epidemic Disease in Nineteenth-Century India* (Berkeley: University of California Press, 1993); Charles E. Rosenberg, "Shaping a Pandemic Narrative Social Research," *Social Research: An International Quarterly* 87, no. 2 (2020); Harrison, "A Global Perspective"; Robert Shannan Peckham, *Epidemics in Modern Asia*, New Approaches to Asian History (Cambridge, UK: Cambridge University Press, 2016); Michael A. Osborne, *The Emergence of Tropical Medicine in France* (Chicago; London: University of Chicago Press, 2014); Warwick Anderson, *Colonial Pathologies: American Tropical Medicine, Race, and Hygiene in the Philippines* (Durham, NC: Duke University Press, 2008); Warwick Anderson, "The Philippine COVIDscape Colonial Public Health Redux?," *Philippine Studies: Historical and Ethnographic Viewpoints* 68, no. 3–4 (2020): 325–37; Worster, *Nature's Economy*; Alfred Crosby, *Ecological Imperialism: The Biological Expansion of Europe, 900-1900* (Cambridge, UK: Cambridge University Press, 2004); Carolyn Merchant, *Radical Ecology: The Search for a Livable World* (Routledge, 2005); Susan D. Jones, "Body and Place," *Environmental History* 10, no. 1 (January 2005); John Robert McNeill and William Hardy McNeill, *The Human Web: A Bird's-Eye View of World History* (New York: W.W. Norton, 2003); Charles Rosenberg, *Explaining Epidemics and Other Studies in the History of Medicine* (New York: Cambridge University Press, 1992).

Earle Ellis collaborated with geologists, geographers, environmental scientists, archaeologists, and oceanographers to reveal the Anthropocene's impacts. Other historians have used case studies to examine the nature of the human, animal, and environmental interfaces.[28]

ZOONOTIC DISEASES IN HISTORY

This section examines ecological and historical perspectives for major zoonotic diseases in history. Table 1 on p. S125 summarizes the most common zoonoses.

The Black Death (Bubonic Plague)

Caused by the zoonotic bacterium *Yersinia pestis*, the plague resulted in large-scale demographic changes and shifting power distribution among social classes. According to Kyle Harper, the plague killed off between a third and a half of Europe's population in the fourteenth century. In William McNeill's classic reconstruction, the plague was endemic in the wild rodent population of the Himalayas, and when the Mongols incorporated that area into their empire, outbreaks proliferated. Plague persists today in rodent populations in various global regions such as the Tibetan Plateau and Africa. It is transmitted to humans by flea or rodent bites.[29]

Historians have examined the Black Death from numerous perspectives. Samuel Cohn highlighted Italy's experience with the sixteenth-century plague, noting epidemics can bring societies together or trigger violence. Guido Alfani compared the socioeconomic impacts of plague during the seventeenth century. Guenter Risse provided insights into the clash of Eastern and Western cultures by examining municipal attempts to control the plague in San Francisco's Chinatown. And Myron Echenberg has highlighted the political, racial, and medical contexts that have allowed the plague to flourish.[30]

Studying Eurasia, Susan Jones and Anna Amramina have examined Anglophone literature of Soviet disease ecology that illuminated the links among animals, insects, microbes, and the

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[28] Erle C. Ellis, *Anthropocene: A Very Short Introduction*, Very Short Introductions (Oxford; New York: Oxford University Press, 2018); Barbara C. Canavan, "Opening Pandora's Box at the Roof of the World: Landscape, Climate and Avian Influenza (H5N1)," *Acta Tropica* 196 (August 2019): 93–101; Barbara C. Canavan, "Riding the Permafrost Rooster Across the Roof of the World," *Technology and Culture*, 2014.

[29] Thomas Butler, "Plague Gives Surprises in the First Decade of the 21st Century in the United States and Worldwide," *The American Journal of Tropical Medicine and Hygiene* 89, no. 4 (October 9, 2013): 788–93; Brown and Nading, "Introduction: Human Animal Health in Medical Anthropology;" William McNeill, *Plagues and Peoples* (New York: Anchor Books, 1989); Kyle Harper, "Pandemics and Passages to Late Antiquity," *Journal of Roman Archaeology* 28 (2015): 223–60.

[30] Samuel K. Cohn, "Pandemics: Waves of Disease, Waves of Hate from the Plague of Athens to A.I.D.S.," *Historical Research* 85, no. 230 (November 2012): 535–55; Samuel Kline Cohn, *Cultures of Plague: Medical Thinking at the End of the Renaissance* (Oxford; New York: Oxford University Press, 2010); G. Alfani, "Plague in Seventeenth-Century Europe and the Decline of Italy: An Epidemiological Hypothesis," *European Review of Economic History* 17, no. 4 (November 1, 2013): 408–30; Guido Alfani and Tommy E. Murphy, "Plague and Lethal Epidemics in the Pre-Industrial World," *The Journal of Economic History* 77, no. 1 (March 2017): 314–43; Myron J Echenberg, *Plague Ports: The Global Urban Impact of Bubonic Plague, 1894-1901* (New York; Chesham: New York University Press, 2010); Guenter B. Risse, *Plague, Fear, and Politics in San Francisco's Chinatown* (Baltimore: Johns Hopkins Press, 2012).

environment to human outbreaks of plague. Next, Rajnarayan Chandavarkar compared the plague with other infectious diseases in India, noting that while the plague was not the deadliest, it did evoke more fear and panic. Finally, William Summers and Mark Gamsa reviewed the Manchurian plague, and Marie Sodikoff tracked plague narratives from Madagascar.[31]

Plague studies now include integrated historical sources with new evidence from paleobiology. For example, the digital archive from Monica Green et al. provides links to biological, archaeological, and documentary materials about the Black Death. Even so, according to Hannah Brown and Alex Nading, anthropologists and historians have often overlooked the disease ecology involved in the persistence of the plague and other pathogens.[32]

Viruses and Bats at the Human-Animal Interface

Bats are the only mammals that fly and are notorious for carrying more viruses than any other species. Contemporary zoonotic viruses such as Ebola, Marburg, SARS, Nipah, MERS, Hendra, and coronaviruses (SARS, MERS, and SARS-CoV-2) have increased scientific interest in bat-borne viruses. Viruses have moved from bats to humans, often through intermediate species, in a spectacular fashion during the twenty-first century.[33]

Historical perspectives of bat-borne zoonoses illuminate the complexity of how biology, science, society, and culture intersect. For example, scholars in Canada have provided an in-depth examination of the impacts of SARS. For a perspective on Ebola, Mark Honigsbaum has

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[31] Susan D. Jones and Anna A. Amramina, "Entangled Histories of Plague Ecology in Russia and the USSR," *History and Philosophy of the Life Sciences* 40, no. 3 (September 2018): 49; Rajnarayan Chandavarkar, "Plague Panic and Epidemic Politics in India, 1896–1914," in *Epidemics and Ideas*, ed. Terence Ranger and Paul Slack (Cambridge, UK: Cambridge University Press, 1992), 203–40; William C. Summers, *The Great Manchurian Plague of 1910-1911: The Geopolitics of an Epidemic Disease* (New Haven: Yale University Press, 2012); Mark Gamsa, "The Epidemic of Pneumonic Plague in Manchuria 1910–1911," *Past & Present* 190, no. 1 (February 1, 2006): 147–83; Genese Marie Sodikoff, "Zoonotic Semiotics: Plague Narratives and Vanishing Signs in Madagascar," *Medical Anthropology Quarterly* 33, no. 1 (March 2019): 42–59.

[32] Varlik, *Plague and Empire in the Early Modern Mediterranean World*; Monica Green et al., "The Black Death Digital Archive Project," Digital Archive, Global Middle Ages, 2019; Monica Helen Green, ed., *Pandemic Disease in the Medieval World: Rethinking the Black Death*, The Medieval Globe, volume 1 (Kalamazoo: Arc Medieval Press, 2015); Varlık, "Rethinking the History of Plague in the Time of COVID-19," 285-93; Brown and Nading, "Introduction: Human Animal Health in Medical Anthropology," 5-23.

[33] Paul W. Ewald, *Evolution of Infectious Disease* (Oxford: Oxford University Press, 1996); Recht, Schuenemann, and Sánchez-Villagra, "Host Diversity and Origin of Zoonoses"; Ernst Mayr, "Driving Forces in Evolution: An Analysis of Natural Selection," in *The Evolutionary Biology of Viruses*, ed. Stephen S. Morse (New York: Raven Press, 1994); Munster, Judson, and Letko, "Ecology of Emerging Zoonotic Viruses"; L.F. Wang and Crameri, "Emerging Zoonotic Viral Diseases," *Revue Scientifique et Technique (International Office of Epizootics)* 33, no. 2 (August 2014): 569–81; Raina K. Plowright et al., "Ecological Dynamics of Emerging Bat Virus Spillover," *Proceedings of the Royal Society B: Biological Sciences* 282, no. 1798 (January 7, 2015); D.T.S. Hayman et al., "Ecology of Zoonotic Infectious Diseases in Bats: Current Knowledge and Future Directions," *Zoonoses and Public Health* 60, no. 1 (February 2013): 2–21; Stephen S. Morse et al., "Prediction and Prevention of the Next Pandemic Zoonosis," *The Lancet* 380, no. 9857 (December 2012): 1956–65.

argued that this virus had a low rank among global health concerns because the disease remained in a remote, forested region of Central Africa. Thus, before the 2014 outbreak in Africa, there wasn't much of an international response to the disease. [34]

Whatever triggers viral zoonoses, the challenge is to intervene before a pathogen reaches animals and humans. Researchers actively study how bats maintain and transmit viruses, in order to ward off the next zoonotic pandemic. The Global Virome Project collects blood samples from rodents, non-human primates, bats, and other wildlife to discover pathogens. COVID-19, the latest emerging zoonotic disease of bat origin, has had devastating global consequences.[35]

COVID-19

Historian Paula Findlen posed an intriguing question: what would fourteenth-century humanist Giovanni Boccaccio say about COVID-19? In the *Decameron,* Boccaccio wrote about the pandemic of his own time and noted that humans failed to care enough for each other. To this point, Charles Rosenberg argued that humans are slow to acknowledge epidemics until the burden of disease becomes impossible to ignore. In this way, epidemics are both biological events and social phenomena. Other scholars, however, have argued that COVID-19 is not an exceptional event, but fits within a well-established global pattern of disease stretching back millennia. Still, our historical understanding of epidemics is shaped by which areas and which time periods we choose to focus on.[36]

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[34] Michael G. Tyshenko and Cathy Paterson, *SARS Unmasked: Risk Communication of Pandemics and Influenza in Canada*, McGill-Queen's/Associated Medical Services Studies in the History of Medicine, Health, and Society 34 (Montreal; Ithaca: McGill-Queen's University Press, 2010); Thomas Abraham, *Twenty-First Century Plague: The Story of SARS* (Baltimore: Johns Hopkins University Press, 2005); Mary Ellen Snodgrass, *World Epidemics: A Cultural Chronology of Disease from Prehistory to the Era of SARS* (Jefferson, NC: McFarland & Co, 2003); Jacalyn Duffin, Arthur Sweetman, and Queen's University (Kingston, Ont.), eds., *SARS in Context: Memory, History, Policy*, McGill-Queen's/Associated Medical Services Studies in the History of Medicine, Health, and Society 27 (Montreal; School of Policy Studies, Queen's University: McGill-Queen's University Press, 2006); Dorothy H. Crawford, *Ebola: Profile of a Killer Virus* (Oxford; New York: Oxford University Press, 2016); Mark Honigsbaum, "Between Securitisation and Neglect: Managing Ebola at the Borders of Global Health," *Medical History* 61, no. 2 (April 2017): 270–94.

[35] Plowright et al., "Ecological Dynamics of Emerging Bat Virus Spillover"; James L. N. Wood et al., "Ebola, Bats and Evidence-Based Policy: Informing Ebola Policy," *EcoHealth* 13, no. 1 (March 2016): 9–11; Dennis Carroll et al., "The Global Virome Project," *Science* 359, no. 6378 (February 23, 2018): 872–74; James L. N. Wood et al., "A Framework for the Study of Zoonotic Disease Emergence and Its Drivers: Spillover of Bat Pathogens as a Case Study," *Philosophical Transactions of the Royal Society B: Biological Sciences* 367, no. 1604 (October 19, 2012): 2881–92; Rahman et al., "Zoonotic Diseases."

[36] Paula Findlen, "What Would Boccaccio Say about COVID-19," *Stanford University: Plagues & Pandemics in World History: A Series of Historical Conversations*, April 2020; Giovanni Boccaccio, *The Decameron*, trans. G.H. McWilliam, Penguin Classics (London: Penguin Books, 2003); Charles E. Rosenberg and Janet Golden, eds., *Framing Disease: Studies in Cultural History* (New Brunswick, NJ Rutgers University Press, 1992); David Jones, "COVID-19, History, and Humility," *Centaurus* 62, no. 2 (May 2020): 370–80.

Erica Charters and Richard McKay noted that the shock of COVID-19 sweeping across the globe has led to a review of the cultural, political, scientific, and geographical contexts of past pandemics. In one study, Frédéric Keck compared COVID-19 in different Asian states to determine what they had learned from the 2003 SARS crisis. With the advent of the COVID-19 crisis, public health experts have reviewed the early warning signs and pondered why the world was so unprepared for the pandemic. For instance, various countries have yet to balance claims of personal liberty and public health demands.[37]

By combining textual and artifactual evidence, historians and academic institutions have improved our understanding of the COVID-19 pandemic. For example, the essay collection headed by Peter Alagona examined COVID-19 within the context of environmental history. Princeton University produced online videos and panel discussions about COVID-19 from historians. Stanford University's *Plagues and Pandemics World History* examined the range of human responses to pandemics over both time and space. The Geneva Environmental Network assembled critical research specific to COVID-19.[38]

HIV-AIDS

The history of HIV-AIDS illuminates how zoonotic pathogens can jump from an animal to a human. The virus that causes AIDS has been traced to about 1921 in a chimpanzee habitat in Central Africa. The chimpanzee version of this disease was passed to humans who hunted them for meat and were exposed to their infected blood. This transmission pathway demonstrates the interplay of zoonotic diseases' ecological, virological, and social aspects. By 1981, HIV-AIDS jolted scientists who had become complacent about pathogens in the developed world. Global Health expert Peter Piot recounted his experience fighting the disease and found that science

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[37] Erica Charters and Richard A. McKay, "The History of Science and Medicine in the Context of COVID-19," *Centaurus* 62, no. 2 (May 2020): 223–331; Brian Dolan, "It Wasn't Supposed to Be a Coronavirus: The Quest for an Influenza A H5N1 Derived Vaccine and the Limits of Pandemic Preparedness," *Centaurus* 62, no. 2 (May 2020): 331–43; Thomas A. C. Reydon, "How Can Science Be Well-Ordered in Times of Crisis? Learning from the SARS-CoV-2 Pandemic," *History and Philosophy of the Life Sciences* 42, no. 4 (December 2020): 53; David M. Morens, Peter Daszak, and Jeffery K. Taubenberger, "Escaping Pandora's Box—Another Novel Coronavirus," *New England Journal of Medicine* 382, no. 14 (April 2, 2020): 1293–95; Keck, "Asian Tigers and the Chinese Dragon"; Michael T. Osterholm, Laurie Garrett, and Lisa Monaco, "The Next Pandemic: Why the World Was Not Prepared for COVID-19," ed. Foreign Affairs Magazine, *Foreign Affairs*, May 31, 2020; Warwick Anderson, "The Model Crisis, or How to Have Critical Promiscuity in the Time of COVID-19," *Social Studies of Science* 51, no. 2 (April 2021): 167–88; Sheila Jasanoff, "Pathologies of Liberty: Public Health Sovereignty and the Political Subject in the COVID-19 Crisis," *Cahiers Droit, Sciences & Technologies*, no. 11 (November 30, 2020): 125–49.

[38] Harvard University Library, "Open Collections Program: Contagion, Germ Theory," Contagion: Historical Views of Diseases and Epidemics, 2011; Princeton University, "Creating a Usable Past: Epidemic History, COVID-19, and the Future of Health," 2020t; "Plagues and Pandemics in World History: A Series of Historical Conversations" (Stanford University History Department, 2020); Peter Alagona et al., "Reflections: Environmental History in the Era of COVID-19," *Environmental History* 25, no. 4 (October 1, 2020): 595–686; "COVID-19 and The Environment," Geneva Environment Network, 2021.

did little good when it operated independently of politics and economics. Moreover, politics is worthless if it rejects scientific evidence.[39]

Historians have contributed much to the HIV-AIDS literature. For example, Victoria Harden noted that HIV-AIDS was the first infectious disease to gain worldwide recognition as a single phenomenon. Harden, along with Guenter Risse, edited *AIDS and the Historian*, drawn from 1989 NIH conference proceedings. Other contributions include Paula Treichler's examination of the cultural aspects of HIV-AIDS. Allan Brandt argued that AIDS led to the new field of Global Health. And Lukas Engelmann produced a visual synthesis of HIV-AIDS history.[40]

Anthrax

Anthrax is a devastating zoonotic disease of horses, sheep, and cattle. This soil-borne bacteria produces spores that survive in the environment for a long time. Susan Jones recounted how anthrax is transmitted to humans by contact with infected animals or by the processing of animal hides. This results in "woolsorters disease" in humans. The local, national, and global significance of anthrax has been studied by James Stark.[41]

Vector-Borne Zoonoses

A vector is an organism that transfers an infection from an animal to a human or another animal. Typical vectors include mosquitoes, ticks, fleas, and lice, which cause diseases like plague, malaria, Zika, West Nile Virus, yellow fever, typhus, dengue, and Lyme disease. Vector-borne zoonoses make abundantly clear the close links between environmental conditions, ecology, and societal responses. For example, Alex Nading examined dengue fever, the world's most prevalent mosquito-borne zoonosis, documenting the entanglement of dengue with poverty, politics, and economic upheaval. Equally important, John McNeil examined ecology and disease in the Greater Caribbean from the seventeenth through early twentieth

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[39] Jacques Pepin, *The Origins of AIDS* (Cambridge, UK; New York: Cambridge University Press, 2011); Claire Laurier Decoteau, "Peter Piot. AIDS between Science and Politics," *Isis* 107, no. 3 (September 20, 2016): 680–81; Lederberg, "Viruses and Humankind," *Frontline: The Age of AIDS*, 1989.

[40] Paula A. Treichler, *How to Have Theory in an Epidemic: Cultural Chronicles of AIDS* (Durham, NC: Duke University Press, 1999); Lukas Engelmann, *Mapping AIDS: Visual Histories of an Enduring Epidemic*, (Cambridge, UK: Cambridge University Press, 2018); Steven Epstein, *Impure Science: AIDS, Activism, and the Politics of Knowledge*, Medicine and Society (Berkeley: University of California Press, 1996); Allan M. Brandt, "How AIDS Invented Global Health," *New England Journal of Medicine* 368, no. 23 (June 6, 2013): 2149–52; Victoria Angela Harden, *AIDS at 30: A History* (Washington DC: Potomac Books, 2012); Victoria A. Harden and Guenter B. Risse, eds., *AIDS and the Historian* (Bethesda, MD: National Institutes of Health, 1989); Alan Whiteside, *HIV and AIDS: A Very Short Introduction* (Oxford: Oxford University Press, 2016).

[41] Susan D. Jones, *Death in a Small Package: A Short History of Anthrax*, Johns Hopkins Biographies of Disease (Baltimore: Johns Hopkins University Press, 2010); James F. Stark, *The Making of Modern Anthrax: 1875-1920; Uniting Local, National and Global Histories of Disease* (London: Pickering et Chatto, 2013).

centuries. He argued that ecological changes made this region prone to yellow fever and malaria vector mosquitoes.[42]

Historical sources show that the transmission of malaria has accompanied agricultural and settlement activities for millennia. For example, Rohan Deb Roy has explored malaria in the context of British colonial rule, science, medicine, and empire. Rachel Dentinger studied monkeys and malaria across biological, geographical, and disciplinary boundaries. James Webb studied malaria control in sub-Saharan Africa, while Leo Slater reviewed the importance of anti-malarial programs in biomedical research. Randall Packard found that war, land development, and globalization, coupled with climate change, cause the proliferation of malaria's carrier mosquitoes.[43]

Influenza: A Promiscuous Multi-Species Virus

Influenza has a remarkable history of interconnected viral webs among birds, swine, horses, and people. Between the seventeenth and nineteenth centuries, influenza was as much a disease of horses as humans.[44] However, data about the human disease can be gleaned from sources going back over five hundred years. The 1918 influenza pandemic was the most devastating

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[42] Tejas S. Athni et al., "The Influence of Vector-Borne Disease on Human History: Socio-Ecological Mechanisms," ed. Jonathan Chase, *Ecology Letters* 24, no. 4 (April 2021): 829–46; Alexander M. Nading, *Mosquito Trails: Ecology, Health, and the Politics of Entanglement* (Oakland, CA: University of California Press, 2014); J. R. McNeill, *Mosquito Empires: Ecology and War in the Greater Caribbean, 1620-1914* (Cambridge, UK: Cambridge University Press, 2010); Jacob Bull, "Between Ticks and People: Responding to Nearbys and Contentments," *Emotion, Space and Society* 12 (August 2014): 73–84; Hans Zinsser, *Rats, Lice, and History* (New Brunswick, NJ: Transaction Publishers, 2008).

[43] Rohan Deb Roy, *Malarial Subjects: Empire, Medicine and Nonhumans in British India, 1820-1909*, 2017; Rachel Mason Dentinger, "Patterns of Infection and Patterns of Evolution: How a Malaria Parasite Brought 'Monkeys and Man' Closer Together in the 1960s," *Journal of the History of Biology* 49, no. 2 (April 2016): 359–95; James L. A. Webb, *The Long Struggle against Malaria in Tropical Africa* (Cambridge, UK; New York: Cambridge University Press, 2014); Leo B. Slater, *War and Disease: Biomedical Research on Malaria in the Twentieth Century* (Piscataway, NJ: Rutgers University Press, 2009); James L. A. Webb, *Humanity's Burden: A Global History of Malaria*, Studies in Environment and History (Cambridge, UK; New York: Cambridge University Press, 2009); Randall M. Packard, *The Making of a Tropical Disease: A Short History of Malaria* (Baltimore: Johns Hopkins Press, 2007); Marcos Cueto, "A Return to the Magic Bullet? Malaria and Global Health in the Twenty-First Century," in *When People Come First: Critical Studies in Global Health*, eds. João Guilherme Biehl and Adriana Petryna (Princeton: Princeton University Press, 2013).

[44] David M. Morens and Jeffery K. Taubenberger, "Historical Thoughts on Influenza Viral Ecosystems, or Behold a Pale Horse, Dead Dogs, Failing Fowl, and Sick Swine," *Influenza and Other Respiratory Viruses* 4, no. 6 (August 4, 2010): 327–37; David M. Morens and Jeffery K. Taubenberger, "Pandemic Influenza: Certain Uncertainties," *Reviews in Medical Virology* (June 27, 2011); Michael Bresalier, "Neutralizing Flu: 'Immunological Devices' and the Making of a Virus Disease," in *Crafting Immunity: Working Histories of Clinical Immunology*, eds. Pauline Mazumdar, Kenton Kroker, and Jennifer Keelan (London: Ashgate Publishing, Ltd., 2008); Floor Haalboom, "'Spanish' Flu and Army Horses: What Historians and Biologists Can Learn from a History of Animals with Flu during the 1918–1919 Influenza Pandemic," *Studium* 7, no. 3 (November 26, 2014): 124.

disease since the plague swept through Europe and Asia in the fourteenth century.[45] By 1952, the World Health Organization (WHO) had established a laboratory network to monitor human flu strains, to project when and where a pandemic would emerge. This endeavor was never fully realized. Significantly, by 1974 researchers had concrete evidence that flu viruses in aquatic waterfowl were the primordial source of all known influenza viruses, including human flu.[46]

Avian influenza Zoonosis

Avian influenza is a zoonotic disease that passes to humans through infected poultry and has a fatality rate of about sixty percent. Fortunately, the infection does not transmit from person to person. Nevertheless, the World Health Organization has characterized the avian influenza in wild birds and poultry farms as a global health crisis. Bird Flu outbreaks among wild and domestic birds in the twenty-first century have already exceeded the total number of outbreaks during the twentieth century. Consequently, there is fear that if an avian influenza virus were to become transmissible from person to person, a major pandemic would ensue.[47]

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Historians, anthropologists, and ecologists have studied avian influenza as a prime example of a cross-species zoonotic pathogen. In one example from Hong Kong in 1997, an avian flu virus (H5N1) was transmitted directly from sick chickens to eighteen people, six of whom died. These were the first recorded human cases of avian flu virus. According to Angela Woods et al., avian influenza made the passage of disease between people and animals much more visible. In subsequent outbreaks beginning in 2005, thousands of migratory birds died near Qinghai Lake on the Tibetan Plateau. Within months, the number of countries with avian flu cases in wild birds or poultry increased from 16 to 55 countries. In nine of these countries, there were human fatalities. These outbreaks of the Qinghai-lineage virus correlated in time and space with bird migration along overlapping migratory bird flyways of Eurasia.[48]

It is noteworthy that the Tibetan Plateau is at the leading edge of global climate change. This may be a factor in the avian influenza outbreaks among wild birds that, in turn, seeded epidemics among domestic poultry in over fifty countries. As a result, disease ecologists have urged research into migratory birds and the impacts of global climate change. According to Susan Jones, birds and other animals have played a vital role in reshaping scientific knowledge. As a case in point, in the Qinghai avian flu case study, a bar-headed goose migrating over the Himalayas became a central actor in the avian influenza story.[49]

The interplay of humans, birds, and other animals across time and space suggests an integrative approach to research. For instance, anthropologist Lyle Fearnley examined bird flu within the contexts of duck husbandry, rice-paddy landscapes, wild bird migration flyways, and live bird markets. Frédéric Keck explored human-animal interactions in China in the context of disruption to the migratory birds' ecology. Similarly, Robert Wallace argued that escalating avian flu outbreaks might be the unintentional "biological fallout" of industrial food production.[50]

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ONE HEALTH: AN INTERDISCIPLINARY BANDWAGON

By 2005, the avian flu crisis among wild birds and chickens accelerated people's interest in "One Health," which deals with the threat of zoonotic disease to both animals and humans. One Health is an approach that recognizes that the health of people is closely connected to the health of animals and our shared environment. Angela Woods et al., Cassidy, and Michael Bresalier have analyzed the emergence and growth of One Health and its historical alignment with animal health and infectious disease.[51]

Ronald Atlas and Stanley Maloy collaborated with researchers to present evidence, successful applications, and the challenges of One Health. Challenges include integrating social sciences and humanities with the environmental sector and diverse scientific disciplines. For example, the Science, Technology, and Society (STS) field currently integrates the contributions of various disciplines, among them ethics, policy analysis, legal studies, sociology. But fields such as STS, History, and the History of Science have different but overlapping approaches and academic structures. As a result, researchers often remain unaware of the collaborative, cross-disciplinary potential of One Health.[52]

Historians and social scientists have raised concerns about the current structure of One Health, since it only superficially covers political and economic processes or the social determinants of human-animal exposure. Scholars suggested reimagining One Health as an entanglement rather than an overlapping diagram to best capture the human-animal complexities.[53] Social scientists Susan Craddock and Steven Hinchliff claim that the One Health

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2020); Frédéric Keck, *Avian Reservoirs: Virus Hunters and Birdwatchers in Chinese Sentinels Posts*, Experimental Futures (Durham, NC: Duke University Press, 2020).

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approach is at risk of derailment outside of an engagement with good social science. According to Lynteris, One Health's emphasis on cross-species relationships falls apart when zoonotic diseases are addressed by culling, stamping out, and eradicating animals.[54]

A more robust version of One Health would incorporate ethnographic studies identifying social and cultural influences that shape human-animal interactions. Robert Wallace advocates this approach in the study of global industries such as chicken farming. Similarly, Lyle Fearnley maintained that ethnographies of people raising livestock provide insights into animal and human entanglements that result in the spillover of pathogens.[55]

CONCLUSIONS

The convergence of animal health, human health, and ecosystem health is the new reality. The same human activities that drive climate change also contribute to pandemic risk.[56] Thus, zoonoses are likely to emerge more often, short of changes in the way we research these human-animal-environment interfaces.

Contributing to deeper understandings of zoonotic diseases, historians and anthropologists have viewed pandemics as social and biological phenomena, as this essay demonstrates. However, viewpoints differ as to whether scholars routinely examine disease links between animals and humans. These links include the ecological aspects of infectious diseases' history and the role of wildlife as vectors of zoonotic disease. In addition, challenges persist in integrating social sciences and humanities, the environmental sector, and scientific research.

Ideally, historiographies of zoonotic diseases would include societies' responses and the social, cultural, political, economic, and ecological contexts. This essay assembles resources that would benefit such an integrated approach. However, this collaboration requires the integration of the work of historians and scholars from other cross-disciplinary fields.

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Table 1. Common Zoonoses

Disease in Humans	Known zoonotic disease reservoir
Anthrax	Infected animal products: wool, hides, leather, or hair
Colorado Tick Fever	Ground squirrels, chipmunks, porcupines, small rodents
COVID-19	Bats; through an intermediate host (unknown)
Dengue	Primates; through mosquito bites
Eastern equine encephalomyelitis	Wild birds, domestic fowl, horses, mules, donkeys
Ebola	Bats
Hantavirus	Rodents
HIV	Chimpanzees
Influenza type A	Swine, domestic, and wild aquatic birds
Lassa Fever	Rodents
Lyme Disease	Ticks
Marburg	Bats
MERS	Bats; through camels
Nipah	Bats; through pigs
Plague	Rodents and fleas
SARS	Bats; through civets
Rabies	Bats, dogs, foxes; through animal bites
Rift Valley Fever	Sheep, goats, cattle, camels; through mosquito bites
West Nile Virus	Wild birds, horses; through mosquito bites
Yellow fever	Monkeys, baboons; through mosquito bites
Zika	Through mosquito bites

Note. Zoonotic Disease Reservoirs: Data from the Centers for Disease Control and Prevention; Forum on Microbial Threats and Institute of Medicine; G. Venkatesan et al.[57]

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