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COVID-19 as an Anthroponosis: Toward a Nonspeciesist Criminology of Human-to-Animal Pathogen Transmission

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Abstract

This paper examines a potentially fatal type of pathogen transmission, namely, the spillover of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) from COVID-19-positive humans to nonhuman animals. This neglected direction of pathogen transmission ("anthroponosis") was first publicized in March 2020, when eight large felids at a zoo in New York City were infected with SARS-CoV-2 by a COVID-19-positive employee. The paper gathers and problematizes the as-yet sparse evidence of anthroponotic transmissions of SARS-CoV-2 at sites in the animal–industrial complex where animals are held captive in zoos; appointed as human companions; used in scientific experiments; and raised and slaughtered in industrialized agriculture. The great fear is that animals infected with SARS-CoV-2 by COVID-19-positive humans will develop mutant strains of the virus, that these variants will be transmitted back to humans, and that the variants will be immune to the vaccines currently in use or in development. When we harm animals, we harm ourselves. Never has the need for a nonspeciesist approach to public health and safety been more urgent.

Keywords

Anthroponosis; COVID-19; nonspeciesist criminology; SARS-CoV-2; theriocide; zoonosis.

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Introduction

In a paper companion to this, I have lamented that, whether as bacterium, fungus, parasite, or virus, the phenomena of pathogen transmission are typically framed in the speciesist worldview of human exceptionalism (Beirne 2021). That is, in respect of the current malaise, COVID-19—the first global pandemic to be caused by a coronavirus—we humans portray ourselves as the sole, the devastated, and the quite innocent victims of a disease transmitted to us by some still-to-be identified nonhuman animal. A key assumption of that earlier paper is that, in respect of the processes of pathogen transmission, a nonspeciesist perspective is not an alternative but a necessary complement to the narrow biological foci of biomedical disciplines, such as microbiology, conservation biology, ecology, epidemiology, infectious diseases, tropical medicine, veterinary science, and biosecurity studies. I urged that "the study of pathogen spillover [can] be greatly enhanced by multi-perspectival approaches, including One Health and ... nonspeciesist criminology" (Beirne, 2021: 607; and see Beirne 1999, 2009, 2014; Beirne with Janssen and O'Donnell 2018; Cazaux; 2007; Sollund 2017a, 2017b, 2019). In other words, there is more to be said about the causes of interspecies pathogen transmission than that they lie exclusively in the internal workings of the bodies of nonhuman animals (henceforth, "animals"). There is more to be said about COVID-19—much more—than that severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) uses the ACE-2 protein receptor for cell entry in humans, for instance.

Agnosticism is at present the most apt watchword for our understanding of the origin of COVID-19 as an outbreak and pandemic. Unresolved questions abound. Did the disease originate in late 2019 as a zoonosis, an animal-to-human infection transmitted at the Huanan Seafood Wholesale Market in the city of Wuhan in eastern China? Did it emerge elsewhere and in more than one location in Wuhan? Or did COVID-19 surface among humans in Wuhan only as the culmination of an infection that began at one of countless other points in the very lengthy chain of legal and illegal international wildlife trade? One must wonder whether the original site of zoonotic transmission will ever be determined.

The precise site of zoonotic pathogenesis is not the only contentious aspect of the emergence of COVID-19. From which of several animal species did humans originally acquire the SARS-CoV-2 virus, the causal agent of COVID-19? In this regard, while rufous horseshoe bats (*Rhinolophus sinicus*) are widely considered the reservoir species of SARS-CoV-2, Malayan pangolins (*Manis javanica*) and Chinese masked palm civets (*Paguma larvata*) are but two among several species suspected to be the intermediate agents of transmission: ferret badgers, hedgehogs, bamboo rats, and certain species of snake also continue to have their proponents.

Further, as the phylogeneticist John Wenzel (2020) complains, it is overly simplistic to conclude that the pathway of transmission for COVID-19 was bat→civet/pangolin→human. He warns that, given how messy and complicated the data are on coronaviruses such as SARS-CoV-2 and SARS-CoV-1, much prominent scientific research has been conducted far too hastily and with dangerous shortcuts. Besides there being genuine doubt about which particular species was the intermediate host, even the direction of pathogen transmission has yet to be determined with any confidence. Regarding the exposure of humans to animals with SARS-CoV-2 in the Huanan market, therefore, there is good reason for Wenzel to worry that it might have been an animal, a pangolin, for example, who acquired the virus from close contact with humans.

While awaiting a convincing epidemiology of COVID-19, this paper examines what is known about the scope and operation of harmful human-to-animal pathogen transmissions ("anthroponoses"). However, as a field of inquiry into the health of our fellow inhabitants of planet Earth, the study of the etiology, incidence, and significance of anthroponosis has very largely been ignored. There is no entry for anthroponosis in the venerable *Oxford English Dictionary*, for instance. It merits mention on only one of the 587 pages of David Quammen's best-selling *Spillover* (2012; and see his overdue self-correction in Quammen 2021). This apparent lack of concern for anthroponosis tends to be confirmed by my search on November 7, 2020, of the Scopus database of books, journals, and conference proceedings worldwide. The search, which was limited to anglophone publications, retrieved 26,748 scholarly citations for "zoonosis" from 1963 to 2020. However, for the same period, "anthroponosis" or "reverse zoonosis" or "zooanthroponosis" yielded only a combined 607 citations. Almost needless to say, a ratio of 44:1 for zoonosis to anthroponosis represents a considerable imbalance in scholarly interest and effort. (Discussion of how much this marked imbalance reflects speciesist prejudice in the biomedical community is beyond my scope here.) More telling still, a search of the World Health Organization's (WHO 2021a) COVID-19 research database from January 1, 2020, to July 31, 2021, found 424 citations for "zoonosis" but only three for "anthroponosis" (a ratio of 141:1).

While the harms wrought within the animal–industrial complex are among the central concerns of scholar-activists in green criminology (e.g., Brisman and South 2020; Goyes et al. 2017; Goyes et al. 2021; Maher, Pierpoint, and Beirne 2017; Nurse and Wyatt 2020; Taylor and Fitzgerald 2018; Taylor and Fraser 2017; White 2011), transmissions from humans to animals are essentially invisible here as well.

This paper, therefore, tries to remedy the neglect of anthroponosis. Its method is threefold. First, I examine the research on anthroponosis cited in the Scopus database (1963–2020) and the WHO COVID-19 research database (January 2020–July 2021). Which citations refer to anthroponosis in passing and which involve analysis and reflection? This research is evenly enough divisible into pre- and post-COVID-19 periods. Second, I focus specifically on the transmission of SARS-CoV-2 by COVID-19-positive humans as found in the biomedical research. Instances of anthroponotic transmission therein I organize into those that occur at four sites: (a) zoos and aquaria; (b) animal companionship in domestic residences and beyond; (c) vivisection; and (d) industrialized agriculture. The order of presentation of these sites implies no necessary priority of one over another in terms of moral culpability or risk assessment for future viral outbreaks and pandemics. Third and finally, I briefly indicate how a doomsday scenario, if left unchecked, could be set in motion by the escalating back and forth of zoonosis and anthroponosis.

Approaching COVID-19 as an Anthroponosis

In approaching COVID-19 as an anthroponosis, a preliminary word or two must be said about the causal process at work in viral transmission. It could well be true, as Wenzel (2020) argues, that coronavirus researchers have often succumbed to pressure for the quick fix of an instant solution and that this encourages numerous methodological errors, including poor taxa sampling, invalid identification, and inadequate distinctions between the root of a viral tree and its branches.

Such errors notwithstanding, the narrow focus of biomedical accounts of pathogen transmission is, for present purposes, limited in two significant ways. On the one hand, the very narrowness of this focus entails a blinkered avoidance of the fact that, besides the vagaries of happenstance, a variety of profit-seeking *anthropogenic* practices has led to the transmission of SARS-CoV-2 and the spread of COVID-19. Chief among these practices are deforestation, wildlife trade, hunting, mining activities, industrial animal production, state-corporate militarism, ubiquitous pollution, and climate crises. Individually and in combination, these practices lead to highly invasive human contact with animals which, in turn, results in the spread of pathogens from one animal to another and from animals to humans.

On the other hand, a narrow biomedical viewpoint seems not to recognize or else to ignore or actively deny that the pathways of pathogen transmission are neither as straight nor as narrow as by convention and research practices it imagines. Harmful pathogens are not only transmitted from animals to humans (i.e., through zoonosis, a nineteenth-century construction from the ancient Greek ζῳον/animal + νόσος/disease). Pathogens are also transmitted from humans to animals or through anthroponosis (from *anthropos*/man[kind] + νόσος), a process that the biomedical literature often, revealingly, refers to as "reverse" zoonosis. Further, whether as zoonosis or as anthroponosis, viral transmissions are not always unidirectional. Pathogens also travel in bidirectional or multidirectional routes (i.e., from one host to another and from one species to another: host and recipient, backward and forward), either from animal to human to animal, or from human to animal to human. In other words, in addition to the pathway of bat→civet/pangolin→human, for example, there are additional potential routes, among them bat→human→civet/pangolin and bat→human→civet/pangolin→human.

A continuing difficulty of grappling with the extant biomedical literature on pathogen transmission, moreover, is that both definitional redundancy and inconsistency are commonplace. This is especially true of the terms used to describe the pathways of zoonosis and anthroponosis. Thus, reverse zoonosis, anthroponosis, and zooanthroponosis are sometimes employed as terms to describe one and the same phenomenon, as too are amphizooanthroponosis, amphizoonosis, amphixenos, and zooanthroponosis for bidirectional or multidirectional transmission. For clarity, this paper will refer to animal-to-human transmission as zoonosis, human-to-animal transmission as anthroponosis, and bidirectional or multidirectional transmission as zooanthroponosis. The term "sapronosis" has been used to describe a pathogen transmission whose source is an abiotic substrate, nonliving environment (Hubálek 2003), although it does not appear elsewhere in this paper.

My attention to existing evidence of COVID-19 as an anthroponosis means that, important as they undoubtedly are, nothing will be said here about numerous other transmissions, whether past *betacoronavirus* pandemics, among which are SARS-CoV-1 in 2002–2003 and Middle East respiratory syndrome coronavirus (MERS-CoV) post-2012, or other potentially fatal anthroponoses, such as *Mycobacterium tuberculosis*, influenza A, human paramoxyvirus, and human respiratory syncytial virus.

Sites of COVID-19 as an Anthroponosis

The absence of a concerted research program on anthroponosis at once raises the problem of how to begin this paper. In this regard, an opening is provided by a scattershot of here-and-there emerging evidence. This suggests that anthroponoses can happen wherever animals are forced closely and overnumerously to interact with humans. Anthroponoses can occur through human-to-animal contact on land, in air, and in water. They can occur in people's homes. They occur on all seven continents. Their confirmed recent victims even include seabirds in Antarctica (Cerdà-Cuéllar et al. 2019).

One of the very few epidemiological investigations of anthroponosis is Messenger, Barnes, and Gray's (2014) essay review "Reverse Zoonotic Disease Transmission." In their review the authors itemize escalating reports of human-to-animal pathogen transmission in 56 countries. In so doing, the authors summarize the number of countries reporting one of the four most common types of anthroponosis, as follows: (1) bacteria in 21 countries, chiefly in North America and Europe; (2) viruses in 16 countries, well-distributed globally; (3) parasites in 12 countries, chiefly in Africa; and (4) fungi or other pathogens in seven countries, predominantly in India. A recalibration of Messenger, Barnes, and Gray's data reveals that 50% of these anthroponoses are of wildlife, 43% of livestock, and 23% of animal companions; 4% are unknown (see also Ali et al. 2011; Nelson and Vincent 2015; Song et al. 2012). To put this finding another way, sites of animal exploitation and of theriocide—of wildlife, of livestock, and of animal companionship in the review above—are predominantly those where the ruling speciesist ideology is animals-as-property and the governing practices are harmful or deadly to animals. These sites are also where SARS-CoV-2 and other dangerous coronaviruses are most likely to cross species barriers as zoonoses or anthroponoses.

The reader should be aware that the very recency of SARS-CoV-2 means that documentation and informed commentary on COVID-19 as an anthroponosis can only be brief, at best.

(a) Zoos and Aquaria

In late March 2020, media and public attention was focused on the Bronx Zoo in New York City where, it had been disclosed, a four-year-old female Malayan tiger was presenting with abnormal respiratory signs. Similar abnormalities—coughing and wheezing with subsequent loss of appetite—were soon thereafter detected in four other tigers and three African lions in the same enclosure. The respiratory secretions and feces of all eight felids, zoo authorities confirmed, were infected with SARS-CoV-2. Epidemiological and genomic sequencing data indicated that the animals had been infected with different genotypes of SARS-CoV-2 (McAloose et al. 2020). This disclosure strongly suggests that the felids had been infected not by one but by *two* independent transmission events. One of these events must have been instigated by an infected zoo employee who transmitted the virus to a tiger and the other by the infected tiger who then passed it on to her fellow felids.

During the first week of public and media scrutiny, the anthroponosis in the Bronx was treated with a mixture of surprise and morbid curiosity. By week's end, once all abnormal respiratory signs in the felids had abated, as had most fecal ribonucleic acid ("RNA") shedding after 35 days, local media reported that public interest had turned mostly to indignation that scarce medical resources had been used on mere animals. Despite the considerable publicity that had initially attended the anthropogenic infection of the Malayan tiger, public interest in her health dwindled very quickly.

Subsequent human-to-animal coronavirus transmissions in other zoos passed mostly underneath the radar of attention. To little or no fanfare:

- Three Malayan tigers tested positive for SARS-CoV-2 at the Knoxville Zoo, Tennessee. It was suspected that they had been infected by an asymptomatic staff member who had been working in close proximity to the animals (Associated Press 2020).

- Four lions contracted SARS-CoV-2 at the Barcelona Zoo in Spain. Two positive-testing staff were likely the agents of transmission (BBC News 2020).

- Three snow leopards tested presumptive positive at the zoo in Louisville, Kentucky, after exposure to humans (USDA 2020a).

- A 17-year-old female tiger with SARS-C0V-2 is reported to have been euthanized at the Boras Zoo in Sweden after she had lost her appetite and her condition worsened (*XINHUANET* 2021). The tiger is presumed to have been infected by a COVID-19-positive employee. Several other large felids and animals of unknown species also displayed clinical signs.

- Two Sumatran tigers tested positive at Fort Wayne Children's Zoo, Indiana (Berger 2021). The source of infection was not officially confirmed.

- A cougar and a tiger tested positive at an unnamed facility that exhibits wild animals in Texas (*New York Times* 2021).

- In July 2020, a puma in Johannesburg Zoo, South Africa, tested positive after contact with an infected worker (CDC 2020).

- Two white tiger cubs at a zoo in Lahore, Pakistan, died from severe lung damage associated with SARS-CoV-2. A pathologist reported that the cubs probably caught the disease from an infected worker who had handled and fed them (*The Independent* 2021).

- A snow leopard at San Diego Zoo tested positive in July 2021. This nine-year-old male had shared an enclosure with a female snow leopard and two Amur leopards. How he contracted the virus is not yet known (*Guardian* 2021).

Large felids are not the only species held in zoos who are known to have acquired SARS-CoV-2 there. For example, after having exhibited respiratory symptoms, such as sneezing, runny noses, lethargy, and coughing, seven Asian small-clawed otters (*Aonyx cinereus*) tested positive at the Georgia Aquarium in the United States (Georgia Aquarium 2021). In another case, a troop of eight western lowland gorillas (*Gorilla gorilla*) acquired the virus at San Diego Zoo Safari Park, California (USDA 2021a). Another outbreak involved more than a dozen western lowland gorillas who tested positive at Zoo Atlanta, where employees were not required to be vaccinated against the virus (Emerson 2021).

In all three of these cases, just as it was with the felids mentioned earlier, zoo officials confirmed that the animals had very likely contracted the virus from COVID-19-positive employees. This is troubling indeed. The humans who staff and in one way or another populate zoos, ecotourism, and wildlife trade pose an enormous threat not only to the future health and safety of gorillas but also to that of other great apes (orangutans, bonobos, and chimpanzees), as they also do for all the other nonhuman primates (Bannerjee, Mossman and Baker 2021; Melin et al. 2020; Van Hamme et al. 2021). In addition to Asian small-clawed otters, other members of the *Mustelidae* family are similarly threatened by anthroponoses, including COVID-19. In this regard, there will be cause enough to return shortly to the precarious situation of ferrets and minks and to the farming of the latter for their fur.

It is hard, perhaps impossible, to know how representative these particular captive animals are of the totality of cases in which COVID-19-positive humans have infected animals with SARS-CoV-2 in zoos. That the cases occurred in well-known zoos accredited either by the Association of Zoos and Aquariums (AZA) or by the World Association of Zoos and Aquariums (WAZA) is not mere coincidence, but how accurate are the reports of these zoo overseers? It defies belief that of AZA's 10,000 accredited zoos worldwide, which are stated to have "high standards of animal care, science, and conservation," and WAZA's 400, which are well-funded elite institutions concentrated in the United States and Europe, only a very few actually had anthroponotic infections of SARS-CoV-2 in 2020 and 2021. One needs additionally to ask: What counts as a "zoo" in this erstwhile epidemiology? How, precisely, are AZA's and WAZA's member zoos distinguishable from non-accredited zoos? How do AZA and WAZA's 10,400 zoos differ from zoological gardens and zoological parks, and how do those self-titled institutions differ from or overlap with menageries, dolphinariums, reptile centers, animal theme parks, wild kingdoms, safari parks, and other sites of animal captivity? How does this bevy of animal enclosures differ from unlicensed private "roadside" zoos? Distressingly, according to the Animal Legal Defense Fund (2018):

Roadside zoos dot the American landscape. They're generally small menageries where wild animals like lions, tigers, monkeys, wolves, and others are kept in captivity, and often suffer badly. The animals frequently live in small, dirty cages. They are fed inadequate food and are denied medical care. They have little in the way of mental stimulation—often, not even the company of other animals, since many roadside zoos keep animals confined alone in their cages. Sometimes roadside zoos also encourage dangerous interactions between animals and visitors, such as bottle-feeding tiger cubs.

About all of the at-risk animals in zoos and roadshows mentioned above, it must be asked: Why are these beings forced to live and suffer in captivity? Tigers and lions in New York City. Malayan tigers in Tennessee. Snow leopards in Kentucky and San Diego. Sumatran tigers in Indiana. Pumas in Johannesburg. Lions in Barcelona. White tiger cubs in Lahore. A tiger in Boras. Asian otters in Georgia. Gorillas in California and Georgia. Whose pleasure does the pain and the deprivations of these animals serve? And for what purpose? Unfangled dominionism? Speciesist spectacle? Colonial or postcolonial prestige?

(b) Companion Animals in Domestic Residences and Beyond

For quite some time, it has been suspected that humans with respiratory ailments are able to transmit pathogens to their live-in animal companions (WHO 2003: 27–28)—to dogs, cats, hamsters, and rabbits, in particular (Gaudreault et al. 2020; Lam et al. 2020; Meekins et al. 2020; Shi et al. 2020). But it was the publicity attending the Bronx infection of felids with SARS-CoV-2 that led to or was coterminous with the discovery of anthroponotic transmissions in a number of animal companions. In April 2020 and thereupon quite rapidly, an indeterminate number of household cats tested positive for SARS-CoV-2 in the Netherlands, France, Hong Kong, Belgium, Spain, and the United States. The virus was then detected in companion dogs in the United States and Hong Kong (Shi et al. 2020; Sit et al. 2020; Yoo and Yoo 2020).

Recent empirical studies vary considerably in their results and in their quality. One study in France—of nine cats and 12 dogs whose owners were COVID-19 positive—found no presence whatsoever of SARS-CoV-2 in the animals (Temmam 2020). Somewhat similarly, also in France, a study of companion animals in treatment at veterinarians and on pet hospital campuses examined 22 cats and 11 dogs who had lived in close contact with COVID-19-positive owners. The animals ranged in age from six months to 16 years. All the animals exhibited clinical signs, among which were anorexia, hyperthermia, lethargy, diarrhea, coughing, broncho-pneumonia, and respiratory distress. However, of these 33 animals, only a nine-year-old female cat (of "a European breed") was found to have SARS-CoV-2 (Sailleau et al. 2020).

Yet, an ongoing study in the United States has provisionally found that in more than 25% of homes with COVID-19-infected humans, companion dogs, or cats (n = 17) had confirmed SARS-CoV-2 infections (Hamer et al. 2020). In all cases, the animals initially had only mild symptoms, such as sneezing or lethargy; on re-examination, each animal was reported to be in good health. In Northern Italy, a much larger study has found that 3.3% of 603 companion dogs and 5.8% of 316 companion cats tested positive for SARS-CoV-2 and that positive-testing animals were significantly more likely to be living in households with a COVID-19-positive inhabitant (Patterson et al. 2020). Another study, in Hong Kong, tested 50 cats who were either from COVID-19-positive households or had close human contacts. This study found six cases of human-to-feline transmission involving healthy cats. In one case, significantly, the virus genomes sequenced in cat and owner were identical (Barrs et al. 2020; see also Zhang et al. 2020).

This handful of studies points to the unmistakable conclusion that companion cats and dogs are more likely to be infected with SARS-CoV-2 if they live with human owners who are COVID-19-positive. But how much more likely is this so and in what circumstances remain open questions. None of these studies is based on random samples of human owners or companion animals, and none is longitudinal. The human owners are those who have somehow had contact with medical doctors and other recognized officials and subsequently been categorized as symptomatic. The animal companions are only those whom their owners have reported to veterinarians as symptomatic and then, if testing positive, have been recorded as such in medical records. In addition, because there are no longitudinal studies on this issue, the long-term health effects of SARS-CoV-2 on animals are unknown. One has to wonder if companion animals can suffer from "long Covid"?

There are avenues aplenty still to pursue about COVID-19 and animal companionship. For instance, there has been no exploration of possible infections of companion animals when the human owners are temporarily or permanently unhoused or living in institutions for the elderly, the unwell, the infirm, the incarcerated, or the otherwise cloistered. What if animal companionship is temporary or unstable, as it often is, for example, between humans and feral animals? Nor is it known whether animal companions other than cats and dogs are vulnerable to their COVID-19-positive owners. One unconfirmed report from Slovenia has it that a companion ferret with digestive signs was detected with SARS-CoV-2 after contact with a COVID-19-positive human (cited in Fennolar et al. 2021). How vulnerable to infection are companion fishes, hedgehogs, horses, minks, and marmoset monkeys, to name but a few other species? Suppose, in addition, that humans use some of these species for hunting, such as horses are for foxes and ferrets for rabbits. Who will transmit and who will contract SARS-CoV-2 in such pursuits?

(c) Vivisection

When using live animals in experiments and observations, the biomedical sciences draw a fundamental distinction between vivisection and studies of animals found in "the field" or in "their natural state." Vivisection is the practice of dissecting or cutting into or otherwise inflicting injury on living animals held for purposes of research. It is conducted chiefly in educational institutions, in product safety testing, and in scientific experimentation, including medical and military research. Conducted with or without anesthesia, it is likely to cause animals pain, suffering, distress, or lasting harm, including death. Sometimes, to observe animals' reactions to measured increments of a painful application, the infliction of pain is the desired aim of vivisection.

Globally, according to some estimates (e.g., Regan 2007; Taylor and Alvarez 2020), hundreds of millions of animals are used in vivisection procedures each year. Controlling for variation in core terms such as "animal" and "procedure," Taylor and Alvarez documented the raw number and rates of vivisection performed by different countries on mammals, birds, reptiles, amphibians, fishes, and cephalopods. Based on reports from 37 countries, the best estimate is that 192.1 million vivisection procedures were performed on live animals worldwide in 2015 (Taylor and Alvarez, 2020). Vivisection is used most often in China, Japan, the United States, and Canada. Some countries intentionally exclude certain species from their publicly accessible data on vivisection. The United States, for instance, does not include mice, rats, birds, fish, reptiles, amphibians, or cephalopods in their publicly accessible data. Some countries provide no publicly accessible data whatsoever, including China, Brazil, India, Taiwan, Iran, Turkey, Mexico, Russia, Egypt, Argentina, Singapore, South Africa, Saudi Arabia, Thailand, Chile, Malaysia, Pakistan, Tunisia, Nigeria, Serbia, Colombia, Kenya, Vietnam, Indonesia, and Uruguay. Contrary to popular perception of their recent decline, vivisection procedures are estimated to have increased by 36.9% worldwide since 2005 (Taylor and Alvarez 2020: figure 2).

In respect of SARS-CoV-2, biomedical scientists perform vivisection with two self-stated aims. The first and overriding aim is to develop vaccines or therapeutics against COVID-19. In early 2021, several vaccines were approved and distributed to recipients in a small minority of nations—among the earliest vaccines, famously, were Sputnik 5, Pfizer-BioNTech, Moderna, Oxford-AstraZeneca, Johnson and Johnson/Janssen, and Sinovac Biotech. By mid-2021, at least 150 health-related organizations and research laboratories were at work developing new vaccines (Goyail et al. 2021; UK Medical Research Council 2021). As experimental models for developing COVID-19 vaccines, the species most frequently used have been golden Syrian hamsters, hACE2-transgenic or adenovirus-transduced mice, and rhesus macaque monkeys. Because they share approximately 93% of their DNA sequences with humans and they are reported to reproduce relatively well in captivity, macaques are often referred to as the gold standard of animals used in vivisection (Cleary et al. 2020; Lakdawala and Menachery 2020; and see Jiao et al. 2021; Lee and Lowen 2021). With an inevitable dwindling in the supply of macaques, researchers have called for an expansion of vivisection on other nonhuman primates, such as baboons (Chang, Hild and Grieder 2021).

The second aim of vivisection, subordinate to the first, has been to determine which species are or might be significant carriers of SARS-CoV-2. This is intended to aid in identifying the species that originally infected humans with the virus. For future risk assessment and risk mitigation, this will improve understanding of which species serve as reservoirs and which as intermediate hosts of the virus, thereby enabling prediction of which species might host zoonotic transmissions and which might be recipients of anthroponoses.

For determining the susceptibility of a given species to SARS-CoV-2, the most common methodology is to begin with a number of pathogen-free members ("subjects," "objects," or "products") of that species, such as rhesus macaque monkeys. The macaques are then divided into two groups, each isolated from the other. One group ("principals") is then "challenged" (i.e., infected) with the virus. This is achieved either intranasally or orally or intratracheally. The macaques in the other group ("sentinels") are then exposed to the infected macaques. After daily observation for clinicopathological abnormalities, such as lethargy, coughing, sneezing, inappetence, and viral shedding, theriocide awaits the survivors. That is, principals and sentinels alike are "sacrificed" or "euthanized" or even, it is occasionally stated, "humanely" sacrificed or euthanized. Postmortem examinations are then conducted on the blood, fluids, tissues, and feces of both macaque groups. Finally, the course of the disease in the infected principals is determined, as is also, if it replicates in the group of exposed sentinels, the degree of severity of the disease. The hope-filled question is now reached: Are virus-neutralizing antibodies present in sera?

Although little or no susceptibility has been found in chickens, turkeys, Pekin ducks, Japanese quails, and white Chinese geese, vivisection has established that a wide range of animal species is susceptible to SARS-CoV-2 (e.g., Suarez et al. 2020). Among the numerous species used and killed to establish this finding are fruit bats, cats, civets, white-tailed deer, dogs, raccoon dogs, ferrets, hamsters, mice, common marmosets, minks, African green monkeys, cynomolgus monkeys, rhesus macaque monkeys, pigs, rabbits, tree shrews, and voles (Bannerjee, Mossman and Baker 2021; Munnink et al. 2021; Palmer et al. 2021).

The painful horrors to which animals are routinely subjected during vivisection need not be rehearsed here. Much awaits to be exposed about how and by whom animals are ordered and delivered for vivisection. Green criminologists are well positioned to uncover vital intersectional knowledge of the complex trade routes, legal and illegal, national and international, whereby commodified animals are hunted, abducted from their homes, held captive, and eventually sold for biomedical research on COVID-19 or other pathogens (Goyes and Sollund 2018; Maher and Wyatt 2017; Maldonado and Lafon 2017; Menache 2017; Phillips and Bellotti 2017). Sometimes, as is the case with nonhuman primates, animals are captured within or near exploited indigenous communities in economically disadvantaged countries and then hauled vast distances to research laboratories in rich countries. At other times, primate species are acquired from breeding facilities, near and afar, with the imprimatur of state approval (e.g., that of the Home Office's Animals in Science Regulation Unit in the UK). At still other times, animals used in commercial, state, or military laboratories or in medical and veterinary schools are simply snatched ("requisitioned") from local animal shelters.

Vivisection is one of the major targets of the animal protection community. Indeed, the pioneering animal rights theorist Tom Regan once confided in me—after I had solicited an original chapter on vivisection from him for a collection my colleague, Professor Nigel South, and I were editing on green criminology—that he regarded vivisection as the very worst of all harmful crimes (and see Regan 2007).

An overdue and probably very divisive debate surely looms in the animal protection community about the role of vivisection in the development of vaccines designed to ameliorate and end the COVID-19 pandemic. This terrain is, of course, hotly contested, and not only between those subscribing to animal welfare and those who support animal rights. This debate will presumably also pit champions of abolitionism against act utilitarianism and consequentialism, the former drawing inspiration from Regan's (1983) *The Case for Animal Rights*, the latter from Singer's (1975: chapter 2) *Animal Liberation*. But between the demand for total abolition, on the one hand, and the view, on the other, that the rightness or wrongness of any act must be measured against the utility of its foreseeable consequences, there appears to be no middle ground. Can vivisection—speciesism—be justified as a measure of self-defense if it averts a "great(er)" tragedy for *human* animals? Hopefully, this debate will encourage the development of real alternatives to vivisection, such as in vitro and in silico research on viruses.

(d) Industrialized Agriculture

It has yet to be determined precisely which of the many animal species reared and killed in industrialized agriculture are prone to SARS-CoV-2 infection from humans who work or reside there. But members of the *Mustelidae* family appear to be especially at risk. Among them are badgers, ferrets, martens, minks, otters, skunks, weasels, and wolverines. In addition to their susceptibility to SARS-CoV-2 transmitted by members of their own species, ferrets (*Mustela putorius furo*) and minks (*Neovison vison*), especially, are known to be at high risk of victimization. This risk is twofold: by intensive farming for their fur and skin and then by SARS-CoV-2 transmitted to them by humans (Bannerjee, Mossman, and Baker 2021; Munnink et al. 2021).

Indeed, only a few days after the SARS-CoV-2 infection of the felids at the Bronx Zoo, it was reported in mid-April 2020 that COVID-19-positive humans had infected minks at two mink farms in North Brabant, The Netherlands. In June 2020 and onwards, infections of minks were reported at thousands of mink farms, successively in France, Spain, Italy, the United States, Sweden, Canada, Greece, Poland, and Lithuania (Fenollar et al. 2021; Munnink et al. 2021; World Health Organization, Food and Agriculture Organization of the United Nations and World Organisation for Animal Health 2021). Moreover, at least one wild (non-captive) mink in Utah has been confirmed as having been infected with COVID-19 (USDA 2020b) and two wild minks, caught in Valencia, Spain, during an invasive species trapping campaign, appear to be SARS-CoV-2-positive (Aguiló-Gisbert et al. 2021).

In what rapidly became a zooanthroponotic event in Holland, infected minks reinfected workers, caregivers, and mink transporters. According to Munnink et al. (2021: 172; and see Hamer et al. 2021; Koopmans 2021):

the virus was initially introduced from humans and has since evolved, most likely reflecting widespread circulation among mink in the beginning of the infection period several weeks prior to detection. Despite enhanced biosecurity, early warning surveillance and immediate culling of infected farms, transmission occurred between mink farms in three big transmission clusters with unknown modes of transmission … 68% of the tested mink farm residents, employees and/or contacts had evidence of SARS-CoV-2 infection. Where whole genomes were available, these persons were infected with strains with an animal sequence signature, providing evidence of animal to human transmission of SARS- CoV-2 within mink farms.

This news rocked the biomedical community and galvanized the health ministries of countries in which SARS-CoV-2 was known to have been transmitted through zooanthroponosis. The Dutch government quickly proposed the theriocide of all minks on infected farms. A month later, similarly tragic circumstances unfolded in Western Europe's largest producer of mink furs, Denmark, where an estimated 17 million minks were gassed or, on occasion, shredded. Several months later, the badly decaying bodies of four million minks, disposed of in fields after they had been killed, were polluting groundwater, forcing Danish authorities to disinter and incinerate them (*Agence France Presse* 2021). To these minks themselves, of course, it likely mattered not one whit if, because they had SARS-CoV-2, they were to be gassed, electrocuted, drowned, or burned, or else, because humans are desirous of their fur, skinned.

One might think that the attempt to ban mink farms would hasten the total abolition of mink slaughter. Not so. Not even close. The consumerist vacuum left by the withdrawal of mink farming in some parts of Western Europe will likely be filled by more intensive mink farming elsewhere in the world—most obviously in Russia, China, the United States, Vietnam, and Thailand. These five countries have mostly maintained a curious silence about their fur farming activities during and after the discovery of SARS-CoV-2 and the subsequent carnage of minks on the farms of their western competitors. One must wonder, too, how many animals might have been infected by the 7.6 million workers on fur farms in China alone (Chinese Academy of Engineering 2017: ii).

The mink theriocides have been said by some biomedical researchers to be a sad sideshow to the COVID-19 pandemic. In fact, it turns out that infected minks are less a sideshow than a star turn in a doomsday scenario for humans. The great fear is that minks or other species infected with SARS-CoV-2 by COVID-19-positive humans will develop mutant strains of the virus, that these variants will then be transmitted back to humans, and that the vaccines currently in use or in development will be rendered less effective. When we harm animals, in other words, we harm ourselves.

Conclusion

The paper has gathered and, to some extent, problematized the currently sparse evidence of anthroponotic transmissions of SARS-CoV-2 at sites in the animal–industrial complex where animals are held captive in zoos; appointed as human companions; used in scientific experiments; and raised and slaughtered in industrialized agriculture. It is a work in progress. Hopefully, given the diverse harms and immense costs of the COVID-19 pandemic, it at least signals that the need for a nonspeciesist approach to public health has never been more urgent.

Postscript

According to the WHO's (2021b) pandemic dashboard, on September 9, 2021, there were 221,648,869 confirmed human cases of COVID-19 worldwide, including 4,582,338 deaths. There was no mention whatsoever of nonhuman animals infected, deceased, or destroyed by the virus.

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