On the Political Ecology of Zoonotic Spillover

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The appearance of energetic action against the pandemic is but a semblance. The writing has been on the wall about zoonotic spillover for years, and states have done as much to address it as they have done to tackle anthropogenic climate change: nothing. 'Zoonotic spillover' is less of a household term – but that should now change – referring to an infection that first sits in an animal and then jumps into a human. A pathogen spills over the species boundary. It could be a worm, a fungus, a bacterium, an amoeba or a virus; of whatever sort, the pathogen is a miniscule creature that eats its prey from within. Paragon of the parasitic, it infiltrates a body and leads its existence inside it, feeding, reproducing and, in the process, inflicting damage upon the host.[1]

'Coronavirus' is a family of viruses with special proficiency in this regard. It gets its name from the appearance of the molecule under the microscope: a greyish ball with dozens of red spikes, looking somewhat like a royal crown or *corona* in Latin – a ubiquitous image in the spring of 2020, crowning it the organism if not person of the year. With the spikes working like hooks, the virus can drive itself into other cells and hold on to them. Like so many others in its family,

[1] Based on David Quammen, *Spillover: Animal Infections and the Next Human Pandemic* (New York: W. W. Norton, 2012 [all page numbers refer to the e-book edition, the print edition rapidly going out of print when Covid-19 started]), 5, 13, 17–18, 38–9, 293–4, 302–3, 347–8, 574; Richard Levins, Tamara Awerbuch, Uwe Brinkmann et al., 'The Emergence of New Diseases', *American Scientist* 82 (1994), 53–7.

this particular coronavirus, formally designated SARS-CoV-2 by the WHO, escaped from its original hosts among bats. But why would it ever do that?

Under normal conditions, coronaviruses and other zoonotic pathogens lead an inconspicuous existence in the wild.[2] They hitch ride after ride on their natural or 'reservoir' hosts – an animal that harbours the parasite and puts up with it, suffering little if any illness. Over millions of years, the viruses have co-evolved and reached a *modus vivendi* with these hosts, permanently inhabiting their bodies without killing them, which could be suicidal. Sometimes a couple of monkeys or mice might fall ill and drop dead on the forest floor, but the generous vegetation would scoop up their carcasses before humans had reason to notice.

Tropical forests house the greatest abundance of species; their ranks thin out near the poles. Ice ages have periodically wiped the slates of evolution clean on high latitudes, where there is less insolation. Around the equator, flora and fauna have been spared glaciers and luxuriated in the energy streaming in from the sun, making tropical forests nurseries of the most astounding biotic exuberance. They also have the richest pathogen pools. The closer to the equator, the more hosts and invisible riders, some of which may on occasion strike out into new terrain. For them to succeed, a number of conditions must be fulfilled: the reservoir hosts must shed the pathogen – as in sneezing or coughing or bleeding it out – onto another host, which must be susceptible to infection. If the pathogen is lucky, it happens to be an 'amplifier host', in whose bosom the agent of disease can multiply profusely, try out new genetic combinations, gain momentum and prepare for the next step, which must be similarly successful. Most links of transmission soon reach a dead

[2] This and the next paragraph follow Quammen, *Spillover*, 15–17, 32, 37–8, 386; Raina K. Plowright, Colin R. Parrish, Hamish McCallum et al., 'Pathways to Zoonotic Spillover', *Nature Reviews Microbiology* 15 (2017): 502–10; Raina K. Plowright, Peggy Eby, Peter J. Hudson et al., 'Ecological Dynamics of Emerging Bat Virus Spillover', *Proceedings of the Royal Society B* 282 (2014), 3.

end. Every now and then, however, openings in the barriers align and the pathogens make it all the way into human populations. The shorter the distance, the less of a feat it will be.

This is an old story: bubonic plague and rabies are two notorious examples of zoonotic spillover. They don't seem like particularly modern distempers, at home among flush toilets that smell of perfume, which is why the problem was fairly recently consigned to the past. In the decades after World War II, the most golden age of capitalism, one could learn that 'the Western world has virtually eliminated death due to infectious disease.'[3] Such Panglossian diagnoses somehow carried over into the last years of the second decade of the millennium. In his airport bestseller from 2018, *Enlightenment Now*, Steven Pinker, the leading voice in the choir of bourgeois optimism, revelled in the 'conquest of infectious disease' all over the globe – Europe, America, but above all the developing countries – as proof that 'a rich world is a healthier world', or, in transparent terms, that a world under the thumb of capital is the best of all possible worlds. ' "Smallpox was an infectious disease" ', Pinker read on Wikipedia – 'yes, "smallpox *was*"'; it exists no more, and the diseases not yet obliterated are being rapidly decimated. Pinker closed the book on the subject by confidently predicting that no pandemic would strike the world in the foreseeable future.[4] Had he cared to read the science, he would have known that waves from a rising tide were already crashing against the fortress he so dearly wished to defend.

He could, for instance, have opened the pages of *Nature*, where a team of scientists in 2008 analysed 335 outbreaks of 'emerging infectious diseases' since 1940 and found that their number

[3] US surgeon general William H. Stewart quoted in Levins et al., 'The Emergence', 52. On this golden age optimism, cf. e.g. A. J. McMichael, 'Environmental and Social Influences on Emerging Infectious Diseases: Past, Present and Future', *Philosophical Transactions of the Royal Society B* 359 (2004), 1049–50.

[4] Steven Pinker, *Enlightenment Now: The Case for Reason, Science, Humanism, and Progress* (New York: Penguin, 2018), 64–7, 307. Emphasis in original.

had 'risen significantly over time'.[5] Most were cases of zoonotic spillover, the lion's share of which originated in the wild. A survey published six years later observed the same trend, but identified a gearshift in the 1980s, the decade of HIV, the most renowned modern virus to spill over from animals before SARS-CoV-2 came along.[6] Since then, the list of pathogens imported from other species has extended like a record of running transactions: the Nipah virus, first detected in 1998 in Malaysia; the West Nile virus, coming to New York in 1999; Ebola, striking West Africa to devastating effect in 2014; Zika, rolling through Latin America and the Caribbean in 2015; the coronavirus that caused SARS, rattling the world in 2002; the coronavirus that caused MERS, making the rounds in the Middle East in 2012; a slew of old diseases staging comebacks, sometimes with novel strains – anthrax, Lyme, Lassa fever – and a series of influenzas appearing with the regularity of hurricanes, but given more faceless names: H1N1, H1N2v, H3N2v, H5N1, H5N2, H5Nx and so on.[7] By 2019, the scientific literature referred habitually to the fact that 'infectious diseases are emerging globally at an unprecedented rate', the share made up of zoonoses estimated at between two thirds and three fourths, increasing to nearly 100 per cent for pandemics.[8] It is a secular trend in its own right.

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[5] Kate E. Jones, Nikkita G. Patel, Marc A. Levy et al., 'Global Trends in Infectious Diseases', *Nature* 451 (2008), 990.

[6] Katherine F. Smith, Michael Goldberg, Samantha Rosenthal et al., 'Global Rise in Human Infectious Disease Outbreaks', *Journal of the Royal Society Interface* 11 (2014): 1–6.

[7] E.g. Bryony A. Jones, Martha Betson & Dirk U. Pfeiffer, 'Eco-Social Processes Influencing Infectious Disease Emergence and Spread', *Parasitology* 144 (2017): 26–36; Karl Gruber, 'Predicting Zoonoses', *Nature Ecology and Evolution* 1 (2017): 1–4; Rob Wallace, 'Notes on a Novel Coronavirus', *Monthly Review*, mronline.org, 29 January 2020; Quammen, *Spillover*, 13–14, 17–18. The similarity to hurricanes is noted in Rob Wallace, *Big Farms Make Big Flu: Dispatches on Infectious Disease, Agribusiness, and the Nature of Science* (New York: Monthly Review Press, 2016), 38.

[8] Jason R. Rohr, Christopher B. Barrett, David J. Civitello et al., 'Emerging Human Infectious Diseases and the Links to Global Food Production', *Nature Sustainability* 2 (2019), 445. The higher estimate can be found in e.g. Lin-Fa Wang

That strange new diseases should emerge from the wild is, in a manner of speaking, logical: beyond human dominion is where unknown pathogens reside.[9] But that realm could be left in some peace. If it weren't for the economy operated by humans constantly assailing the wild, encroaching upon it, tearing into it, chopping it up, destroying it with a zeal bordering on lust for extermination, these things wouldn't happen. The pathogens would not come leaping towards us; they would be secure among their natural hosts.[10] But when those hosts are cornered, stressed, expelled and killed, they have two options: go extinct or jump. In his now must-read *Spillover: Animal Infections and the Next Human Pandemic*, published in 2012, David Quammen likens the effect to the demolition of a warehouse. 'When the trees fall and the native animals are slaughtered, the native germs fly like dust' from under the bulldozers.[11] The science is agreed: the secular trend has a very general driver in the economy advancing from the human side all over the wild. Another turn to the non-human world is, after this, a must. It begins with the order Chiroptera.

& Danielle E. Anderson, 'Viruses in Bats and Potential Spillover to Animals and Humans', *Current Opinion in Virology* 34 (2019), 79; the lower in e.g. Smith et al., 'Global Rise', 3.

[9] Peter Daszak, Andrew A. Cunningham & Alex D. Hyatt, 'Emerging Infectious Diseases of Wildlife – Threats to Biodiversity and Human Health', *Science* 287 (2000), 446.

[10] Quammen, *Spillover*, 17, 36–8, 386.

[11] Ibid., 38.

Of bats and capitalists

The world is home to upwards of 1,200 species of bats, as of 2020. With speciation ongoing for at least 65 million years, this is one of the oldest orders of mammals, the second most diverse – only rodents exhibit greater variety – accounting for one fifth of all extant mammalian species. Bats are also the nonpareil carrier of pathogens. While rodents are likely to carry slightly more viruses in absolute terms, on account of their multitudes, bats host far more such guests per species – and yet they do not seem to mind. They are persistently infected, without sign of malaise. There are no reports of mass die-offs of sick colonies. Hence chiropterologists have postulated that bats possess a unique tolerance of viruses, exceptionally powerful immune systems that must spring from some common trait conferred by those millions of years of evolution.[12] What could it be?

All bats have one hallmark ability: they can fly. While some squirrels and lemurs glide or parachute short distances, bats are the sole mammals to power sustained flight by frenetically flapping their wings. This activity does not come for free. To stay in the air, bats have to expend prodigious amounts of energy, driving metabolic rates to the point where their bodily temperatures reach 40°C – think marathon runners – for hours on end. Less sprightly mammals would experience this condition as fever. Fever, of course, is a primary defence mechanism for bodies beset by illness, which seems to imply that bats – for whom this is more like a natural state – could easily produce a little fever to shrug one off. Conversely, viruses that settle on bats must adapt to

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[12] Angela D. Luis, David T. S. Hayman, Thomas J. O'Shea et al., 'A Comparison of Bats and Rodents as Reservoirs of Zoonotic Viruses: Are Bats Special?', *Proceedings of the Royal Society B* 280 (2013): 1–9; Cara E. Brook & Andrew P. Dobson, 'Bats as "Special" Reservoirs for Emerging Zoonotic Pathogens', *Trends in Microbiology* 23 (2015): 172–80; Karin Schneeberger & Christian C. Voigt, 'Zoonotic Viruses and the Conservation of Bats' in Christian C. Voigt & Tigga Kingston (eds.), *Bats in the Anthropocene: Conservation of Bats in a Changing World* (Cham: Springer, 2016), 275; Wang & Anderson, 'Viruses', 79; Plowright, 'Ecological', 3, 5.

feverlike temperatures. The theory, then, is that bats have become bearers of pathogens that cannot impair *their* constitution, but can overpower the weaker immune systems of other mammals. Flight has other consequences too: it allows bats to travel over vast distances – dozens of kilometres each night in search of food, hundreds between roosting sites, more than one thousand between summer and winter grounds – and pick up and disperse pathogens along the way. Bats spend little time on the ground and much in the air, in trees, under roofs, in positions from which they can let drop saliva and excrements on whatever is beneath them. They can move close to humans, into their orchards, fields, houses and stables, if they have reason to.[13]

And bats have a second key trait: they are gregarious. They huddle together in clusters of uncommon density and diversity. Some bats squeeze in 3,000 individuals per square metre and several million per roost; some hang out in ensembles of multiple species, swapping viruses back and forth – a paradise for pathogens and their evolution, and an ideal formula for herd immunity. Bats, in other words, live by breaking the two principal rules of the 2020 lockdowns: do not travel and do not form crowds. This would explain why they are such hypercompetent reservoir hosts, and why their viruses can become so virulent in other settings, as the world has had repeated occasion to learn.[14]

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[13] Guoije Zhang, Christopher Cowled, Zhengli Shi et al., 'Comparative Analysis of Bat Genomes Provides Insight Into the Evolution of Flight and Immunity', *Science* 339 (2013): 456–60; Thomas J. O'Shea, Paul M. Cryan, Andrew A. Cunningham et al., 'Bat Flight and Zoonotic Viruses', *Emerging Infectious Diseases* 20 (2014): 741–5; Aneta Afelt, Christian Devaux, Jordi Serra-Cobo & Roger Frutos, 'Bats, Bat-Borne Viruses, and Environmental Changes', in Heimo Mikkola (ed.), *Bats* (London: Intech Open, 2018), 120–1; Michael Gross, 'Why We Should Care About Bats', *Current Biology* 29 (2019): R1163–5; Schneeberger & Voigt, 'Zoonotic', 264–5; Brook & Dobson, 'Bats', 176–8; Luis et al., 'A Comparison', 2, 6; Plowright et al., 'Ecological', 6; Wang & Anderson, 'Viruses', 85; Quammen, *Spillover*, 394–5.

[14] Luis et al., 'A Comparison', 2, 5; Johnson et al., 'Global', 8; Plowright et al., 'Ecological', 3; O'Shea et al., 'Bat', 741, 743; Afelt et al., 'Bats, Bat-Borne', 121–2; Quammen, *Spillover*, 393–4. There are other factors too, such as bats

The Nipah virus spilled over to humans in a forested area in northern Malaysia when bats were attracted to fruit trees around a pig farm. They shat or otherwise excreted onto the pigs, which served as amplifier hosts, passing the virus on to humans; it caused fever, cough and shortness of breath, worsening into confusion, coma and inflammation of the brain, with a mortality rate nearing 40 per cent. Some 110 people died in the initial outbreak before it was contained.[15] Rabies is deposited in bat reservoirs. So are dozens of other pathogens of well-documented malignancy, including, probably, Ebola.

But the prime speciality of the Chiroptera is corona. SARS was the first coronavirus to unleash a pandemic in the new millennium, taking scientists by surprise and sending them into the caves of southern China to identify horseshoe bats as the reservoir host, whence the virus switched to civets as the amplifier before seizing on humans.[16] The discovery of corona in bats dates to the early years of the millennium, and barely had it been made before the virus struck again: MERS leapt from bats to camels to humans.[17] After these brushes with mass death, more scientists fanned out across the tropics to try to get an idea of what was in store. One team affiliated with the aptly named PREDICT project – the largest of its kind – captured some 12,000 bats in twenty tropical

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alternating between torpor and flight and thereby further boosting their immune defence systems, and their very ancientness, which has allowed for prolonged co-evolution with pathogens; for these and other bat traits, see references above.

[15] Bryony A. Jones, Delia Grace, Richard Kock et al., 'Zoonosis Emergence Linked to Agricultural Intensification and Environmental Change', *PNAS* 21 (2013), 8401; Schneeberger & Voigt, 'Zoonotic', 265–75; Wang & Anderson, 'Viruses', 80–3.

[16] See Jane Qiu, 'How China's "Bat Woman" Hunted Down Viruses From SARS to the New Coronavirus', *Scientific American*, 27 April 2020.

[17] Jie Cui, Fang Li & Zheng-Li Shi, 'Origin and Evolution of Pathogenic Coronaviruses', *Nature Reviews Microbiology* 17 (2019): 181–92.

countries, collected swab samples and returned the animals to the wild and found that the number of coronaviruses per species came close to three. (Thousands of rodents and primates were also tested, but more than 98 per cent of the positive individuals were bats.) This led them to put the probable number of distinct coronaviruses circulating in the whole planet of bats at 3,000.[18] Far from all would be capable of infecting humans – in 2016, a bat colony in southern China dropped a coronavirus onto pigs that made them die from acute diarrhoea, but it failed to penetrate people – although several hundred are likely to have that potential, and many more might be on the way.

Once it hijacks a cell, a coronavirus behaves like a living creature, and indeed coronaviruses are subject to natural selection. They strive to adapt to their surroundings – batten onto the host, survive attacks, exit to another, replicate, perpetuate the lineage – and endure only insofar as they manage these tasks well. And coronaviruses can evolve faster than most. Their genetic information is encoded not in the complex double helix of the DNA, but in the simpler RNA, a molecule with a single strand that can mutate with fantastic velocity – think a relay of sprinters outpacing a heavy carriage – throwing up new genetic combinations to try out against the environment.[19]

SARS-CoV-2 had struck on one particularly splendid advantage: it could leap from host to host *before* inflicting the damage. One human passed it on to the next prior to developing symptoms. Hence the chain of transmission stretched out over continents far more effectively than for SARS, which had the reverse profile – first symptoms, then peak infectivity – and was broken with relative ease. Once again the virus stemmed from bats, and more strains of

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[18] Simon J. Anthony, Christine K. Johnson, Denise J. Greig et al., 'Global Patterns in Coronavirus Diversity', *Virus Evolution* 3 (2017): 1–15. Cf. Gruber, 'Predicting', 3.

[19] Quammen, *Spillover*, 38–9, 302–3, 347–8; James L. N. Wood, Melissa Leach, Lina Waldman 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* 367 (2012), 2; Wang & Anderson, 'Viruses', 85. Coronaviruses are not the only RNA viruses, of course – Nipah and Ebola are some of the others – but their propensity for mutations is higher.

coronavirus are, for a certainty, being hatched. So why don't we just kill them all? The outbreak of Covid-19 in China prompted calls for bat populations to be eradicated.[20] This is a common response to spillovers – Nipah, to take a minor example, induced the slaughter of more than one million pigs near the source – and appears to make some sense. It could be extrapolated further. Why don't we pave over what remains of the wild? If the whole planet looked like Manhattan, surely there wouldn't be so many parasites to pester us.

Insane as the idea might sound, there is an element of logic to it. General biodiversity should correlate with diversity of pathogens.[21] If the former is slashed, one might expect that whole clades of reservoirs, amplifiers and parasites would be taken out. But it can also go the other way. Biologists have put forth the hypothesis of a 'dilution effect', according to which a richness of species *ipso facto* inhibits spillover.[22] If an abundance of animals is present in an ecosystem – say, a

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[20] Huabin Zhao, 'COVID-19 Drives New Threats to Bats in China', *Science* 367 (2020): 1436.

[21] E.g. Toph Allen, Kris A. Murray, Carlos Zambrana-Torrelio et al., 'Global Hotspots and Correlates of Emerging Zoonotic Diseases', *Nature Communications* 8 (2017), 4–6; Anthony et al., 'Global', 11.

[22] See e.g. Andy Dobson, Isabella Cattadori, Robert D. Holt et al., 'Sacred Cows and Sympathetic Squirrels: The Importance of Biological Diversity to Human Health', *PLOS Medicine* 3 (2006): 0714–18; Felicia Keesing, Lisa K. Belden, Peter Daszak et al., 'Impacts of Biodiversity on the Emergence and Transmission of Infectious Disease', *Nature* 468 (2010): 647–52; P. T. J. Johnson & D. W. Thieltges, 'Diversity, Decoys and the Dilution Effect: How Ecological Communities Affect Disease Risk', *The Journal of Experimental Biology* 213 (2010): 961–70; Richard S. Ostfelt & Felicia Keesing, 'Effects of Host Diversity on Infectious Disease', *Annual Review of Ecology, Evolution, and Systematics* 43 (2012): 157–82; Felicia Keesing & Truman P. Young, 'Cascading Consequences of the Loss of Large Mammals in an African Savanna', *BioScience* 64 (2014): 487–95; Hamish Ian McCallum, 'Lose Biodiversity, Gain Disease', *PNAS* 112 (2015): 8523–4; David J. Civitello, Jeremy Cohen, Hiba Fatima et al., 'Biodiversity Inhibits Parasites: Broad Evidence for the Dilution Effect', *PNAS* 112 (2015): 8667–71; Michael G. Walsh, Siobhan M. Mor, Hindol Maity & Shah Hossain, 'Forest Loss Shapes the Landscape Suitability of Kyasanur Forest Disease in the Biodiversity Hotspots of the Western Ghats, India', *International Journal of Epidemiology* 48 (2019): 1804–14; Christine K. Johnson, Peta L. Hitchens, Pranav S. Pandit et al., 'Global Shifts in Mammalian Population Trends Reveal Key Predictors of Virus

forest – some will be incompetent hosts, in which parasites will find scant nourishment and platforms for replication; when biting them, the attempted transmissions go to waste. If, for example, there are plenty of squirrels in a forest, they will take some of the bites from ticks that might otherwise target humans. The unpleasant, sometimes debilitating Lyme disease – in the worst case causing chronic fatigue and cognitive disorders – is conveyed by ticks, which have been shown to waste many of their bites on a species of opossum present in biodiverse forests of North America. The opossum kills the ticks. But in degraded forests it vanishes, while the white-footed mouse, a most competent and tolerant host for the ticks, continues to thrive – indeed more so than ever, as it is relieved of competitors. The depletion of biodiversity removes the buffers.

While the dilution effect remains the subject of theoretical controversy, there is now across-the-board empirical evidence for it as a law: *higher biodiversity means lower risk for zoonotic spillover.*[23] The species that survive assaults on wild habitats tend to be the opportunists and generalists – think mice or weeds – that carry pathogens with ease, reproduce at speed and make

Spillover Risk', *Proceedings of the Royal Society B* 287 (2020): 1–10. Across-the-board evidence: particularly Civitello et al., 'Biodiversity'. For the continued debate, see Chelsea L. Wood, Kevin D. Lafferty, Giuilo DeLeo et al., 'Does Biodiversity Protect Humans Against Infectious Disease?', *Ecology* 95 (2014): 817–32; Taal Levi, Aimee L. Massey, Robert D. Holt et al., 'Does Biodiversity Protect Humans Against Infectious Disease? Comment', *Ecology* 97 (2016): 536–42; Chelsea L. Wood, Kevin D. Lafferty, Giulio DeLeo et al., 'Does Biodiversity Protect Humans Against Infectious Disease? Reply', *Ecology* 97 (2016): 542–5.

[23] Across-the-board evidence: particularly Civitello et al., 'Biodiversity'. For the continued debate, see Chelsea L. Wood, Kevin D. Lafferty, Giuilo DeLeo et al., 'Does Biodiversity Protect Humans Against Infectious Disease?', *Ecology* 95 (2014): 817–32; Taal Levi, Aimee L. Massey, Robert D. Holt et al., 'Does Biodiversity Protect Humans Against Infectious Disease? Comment', *Ecology* 97 (2016): 536–42; Chelsea L. Wood, Kevin D. Lafferty, Giulio DeLeo et al., 'Does Biodiversity Protect Humans Against Infectious Disease? Reply', *Ecology* 97 (2016): 542–5.

themselves at home in the interstices of human settlements. The warehouse can be demolished, but the dust will not go away. In the process of demolition, it will blow straight in our direction.

It wouldn't be the first time humans reacted to infection by taking it out on the bats. In Australia, the flying fox has been harassed and hunted by upset grim men (""They shit on people! It's backwards – let the people shit on them!"" Quammen quotes one supporter of the chase. "'What good are they? Get rid of them! Why doesn't that happen? Because the sentimental greenies won't have it!'"[24]) In Brazil, roosts of vampire bats have been systematically blown up with explosives. But in all investigated cases of culling, the result has been the opposite of the intended: the pathogen loads have been scattered farther afield. Eradicating bats would merely be one more way to lose biodiversity, as they perform critical functions in pollinating plants, dispersing their seeds and keeping pest insects in check. So far, however, the desire to avenge pandemics is a negligible threat. Instead we must examine deforestation.

Deforestation is an engine not only of biodiversity loss, but of zoonotic spillover itself. When roads are cut through tropical forests, patches cleared, outposts placed deeper in the interior, humans come in contact with all the teeming life forms hitherto left on their own. People raid or occupy spaces where pathogens dwell in the greatest plenitude. The two parties stage their most frequent encounters along the edges of fragmented forests, where the contents of the woods can slip out and meet the extremities of the human economy; and, as it happens, generalists like mice and mosquitos, with a knack for serving as 'bridge hosts', tend to flourish in those zones.[25]

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[24] Schneeberger & Voigt, 'Zoonotic', 277–8; Quammen, *Spillover*, 28.

[25] Dickson Despommier, Brett R. Ellis & Bruce A. Wilcox, 'The Role of Ecotones in Emerging Infectious Diseases', *EcoHealth* 3 (2007): 281–9; Jonathan D. Mayer & Sarah Paige, 'The Socio-Ecology of Viral Zoonotic Transfer' in Sunit Kumar Singh (ed.), *Viral Infections and Global Change* (Hoboken: Wiley, 2013), 80–1; Kimberley Fornace, Marco Liverani, Jonathan Rushton & Richard Coker, 'Effects of Land-Use Changes and Agricultural Practices on the Emergence and Reemergence of Human Viral Diseases' in ibid., 136–7; Christina L. Faust, Hamish I. McCallum,

Fragmentation is now the fate of the planet's forests. Some 20 per cent of remaining forested area stands within 100 metres of an edge and some 70 per cent within one kilometre, archipelagos of wooded islands in oceans of cleared landscapes.[26] On the whole, this is a bane for biodiversity, but again less so for parasites. One group of ecologists has recently advanced the intriguing hypothesis that fragmentation *accelerates* the evolution of pathogens, by locking them and their hosts into island-like habitats and pressing them to come up with paths to survival in the restricted space. On each island, there would now be a 'coevolutionary engine' of parasite and host, taking the most advantage of any mutation and genetic drift and driving down its own separate trajectory, so that, paradoxically, pathogen diversity is increased. The engine of deforestation acts to rev up spin-off engines of parasitic experimentation. And this would be going on right next door to the interface with humans.[27]

Whether that particular hypothesis is confirmed or not, it is evident that the hotspots of spillover are the hotspots of deforestation: and they are located in the tropics. That's where the greatest abundance of bats is found. A quarter of the world's bat fauna lives in Southeast Asia,

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Laura S. P. Bloomfield et al., 'Pathogen Spillover During Land Conversion', *Ecology Letters* 21 (2018): 471–83; David A. Wilkinson, Jonathan C. Marshall, Nigel P. French & David T. S. Hayman, 'Habitat Fragmentation, Biodiversity Loss and the Risk of Novel Infectious Disease Emergence', *Journal of the Royal Society Interface* 15 (2018): 1–10; Rodrick Wallace, Luis Fernando Chaves, Luke R. Bergmann et al., *Clear-Cutting Disease Control: Capital-Led Deforestation, Public Health Austerity, and Vector-Borne Infection* (Cham: Springer, 2018), 24–5; Benny Borremans, Christina Faust, Kezia R. Manlove et al., 'Cross-Species Pathogen Spillover Across Ecosystem Boundaries: Mechanisms and Theory', *Philosophical Transactions of the Royal Society B* 374 (2019): 1–9; Keesing et al., 'Impacts'.

[26] Nick M. Haddad, Lars A. Brudvig, Jean Clobert et al., 'Habitat Fragmentation and Its Lasting Impacts on Earth's Ecosystems', *Science Advances* 1 (2015): 1–9.

[27] Sarah Zohdy, Tona S. Schwartz & Jamie R. Oaks, 'The Coevolution Effect as Driver of Spillover', *Trends in Parasitology* 35 (2019): 399–408 (quotation from 403).

where chainsaws and bulldozers have been crashing through tropical forests in recent decades.[28] The result seems to be imposition of chronic stress. Bats have to make up for lost shelter and food, fly back and forth between island patches, navigate hazards and cross enemy territory – a more stressful life than in the contiguous forests of old. How does it impact their health? Much like stress wears out human bodies. In Sabah, a Malaysian province on the northern tip of Borneo, one team of chiropterologists placed traps in and around forest fragments and examined the bodies of the captured bats. They turned out to have smaller body mass, fewer white blood cells – the infantry of the immune system – and generally poorer constitutions than their conspecifics in less disturbed areas.[29] The stress caused by deforestation appears to crack the otherwise impervious defences of bats and trigger 'pulses of viral excretion' – episodes when viruses are shed en masse onto accidental hosts, who might well be humans, as bats deprived of their old habitats seek shelter and food in barns, gardens, villages and plantations.[30] (Bats can do rather well on cacao plantations.) After the forests have fallen in eastern Australia, the flying fox has little choice but to subsist on what the ranches and parks offer. When Brazilian rainforests are cleared for pastures,

[28] Tigga Kingston, 'Response of Bat Diversity to Forest Disturbance in Southeast Asia: Insights From Long-Term Research in Malaysia' in R. A. Adams & S. C. Pedersen (eds.), *Bat Evolution, Ecology, and Conservation* (New York: Springer, 2013), 170, 177–80.

[29] Anne Seltmann, Gábor Á. Czirják, Alexandre Courtiol et al., 'Habitat Disturbance Results in Chronic Stress and Impaired Health Status in Forest-Dwelling Paleotropical Bats', *Conservation Physiology* 5 (2017): 1–14.

[30] Raina K. Plowright, Alison J. Peel, Daniel G. Streicker et al., 'Transmission of Within-Host Dynamics Driving Pulses of Zoonotic Viruses in Reservoir-Host Populations', *PLOS Neglected Tropical Diseases* 10 (2016): 1–21.

the vampire bat, so called because it feeds on blood, is pushed to attack cattle. Similar dynamics come into play for rodents.[31]

Now, if deforestation drives zoonotic spillover in the early twenty-first century, we must ask: what drives deforestation? The cutting down of trees is, of course, an ancient human practice. Like any other such practice, it takes on shifting forms over time. A break occurred in the 1990s.[32] Before that decade, deforestation in the tropics – particularly Southeast Asia and Latin America – was largely initiated by the state. In the 1960s and '70s, peasant insurgencies billowed through the continents, operating from within remote forests in every newly independent country in Southeast Asia – one, two, many Vietnams – and seeking to bring the example of the Cuban Revolution to most corners of Latin America. The US enjoined the governments under its tutelage to stem the tide by colonising their hinterlands, so as to strip the insurgents of cover and undercut their popular support. If smallholders were given the land they craved, they would not go over to the guerrillas, and far better than to expropriate the estates – the very thing the US sought to avoid – was to open up the forests. Hence, the military dictatorship of Indonesia resettled smallholders on the outer islands, while that in Brazil bisected the Amazon with a mega-highway and dispatched pioneers to stake out their own land claims along feeder roads. Come the 1990s, the insurgencies had all been defeated, while the structural adjustment programmes compelled states to improve their finances and trade balances. The drivers were inverted. A global shift in the balance of class

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[31] Aneta Afelt, Roger Frutos & Christian Devaux, 'Bats, Coronaviruses, and Deforestation: Toward the Emergence of Novel Infectious Diseases?', *Frontiers in Microbiology* 9 (2018): 1–5; Christoph F. J. Meyer, Matthew J. Struebig & Michael R. Willig, 'Responses of Tropical Bats to Habitat Fragmentation, Logging, and Deforestation' in Voigt & Kingston, *Bats*, 81–2; Plowright et al., 'Ecological', 3–4; Quammen, *Spillover*, 417–18.

[32] This paragraph sticks closely to Thomas K. Rudel, Ruth DeFries, Gregory P. Asner & William F. Laurance, 'Changing Drivers of Deforestation and New Opportunities for Conservation', *Conservation Biology* 23 (2009): 1396–1405 (quotations from 1398, 1400).

forces caused a transmutation in deforestation: it became 'enterprise-driven', in the terms of a seminal meta-analysis. The state took a step back and concentrated on transferring titles to cheap land and labour. The initiatives to clear forests now came from 'highly capitalized, well-organized' private actors, who built the roads and sent their machines to make way for plantations, quarries and ranches or to log the timber, with an eye to some distant market. The state no longer advanced into the forests with a troop of ragged smallholders behind it: another force smashed into them for its own purposes.

In the new millennium, it is the production of commodities that chews up tropical forests. It negates diversity on every front. No more than four commodities – beef, soybean, palm oil and wood products, in descending order of impact – accounted for four tenths of the dramatically sped-up tropical deforestation between 2000 and 2011, split among seven countries in Southeast Asia and Latin America.[33] The historical break was visible from above. Smallholders make for small clearings, while enterprises with operations on industrial scale make for large ones, palm oil plantations regularly covering more than 3,000 hectares in Indonesia and cattle ranches more than 1,000 in Brazil. Hence the size of a clearing is a proxy of the driver, and the most recent available analyses of satellite maps show that the bulk of deforestation in the first decade of the millennium took the shape of large and medium-size clearings, beyond the means of smallholders; the trend was most salient, again, in Southeast Asia and Latin America, scenes of the largest total losses.[34]

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[33] Sabine Henders, U. Martin Persson & Thomas Kastner, 'Trading Forests: Land-Use Change and Carbon Emissions Embodied in Production and Exports of Forest-Risk Commodities', *Environmental Research Letters* 10 (2015): 1–14. Cf. e.g. Patrick Meyfroidt, Kimberley M. Carlson, Matthew E. Fagan et al., 'Multiple Pathways of Commodity Crop Expansion in Tropical Forest Landscapes', *Environmental Research Letters* 9 (2014): 1–13.

[34] Kemen G. Austin, Mariano González-Roglich, Danica Schaffer-Smith et al., 'Trends in Size of Tropical Deforestation Events Signal Increasing Dominance of Industrial-Scale Drivers', *Environmental Research Letters* 12 (2017): 1–10.

What stresses the bats in Sabah? It is palm oil plantations that creep up on their habitats.[35] Malaysia and Indonesia together produce 90 per cent of all palm oil in the world, 70 per cent of agricultural land in the former country now devoted to this one commodity. It puts Malaysia in the top league for the largest clearings. No other nation lost old-growth forests as fast during the first decade of the century, when they were razed to make room for mono-crop fields interspersed with mills; the oil must be squeezed from the palm within 24 hours of harvest. The plantations are owned by some of Malaysia's biggest companies, fully integrated in global financial circuits, indispensable as a source of upfront investments, the mills and refineries plugged into networks of roads, trucks, harbours and tankers that can ferry the product to any market. Thousands of workers lodge on the plantations in huts provided by the companies.[36] In Sabah, one researcher uncovered a pattern of predominantly immigrant workers held in debt bondage – indebted upon arrival; passports confiscated; intimidated by police; food available only on credit, compounding their debt – and often paid below the legal minimum wage.[37] What do these enterprises aim to achieve? 'Plantation companies and their shareholders', writes one group of forest ecologists, 'seek to maximize the marginal returns to their capital and seek access to large expanses of cheap, unencumbered land with access to reliable low-cost labour.'[38] These are – there is no other term for it – eminently capitalist enterprises. As such they are subject to the compulsion to expand.

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[35] Seltmann et al., 'Habitat', 2–3.

[36] David L. A. Gaveau, Douglas Sheil, Mohammed A. Salim et al., 'Rapid Conversions and Avoided Deforestation: Examining Four Decades of Industrial Plantation Expansion in Borneo', *Nature Scientific Reports* 6 (2016): 1–13; Henders et al., 'Trading', 1; Austin et al., 'Trends', 5; Oliver Pye, 'Commodifying Sustainability: Development, Nature and Politics in the Palm Oil Industry', *World Development* 121 (2019): 218–28; Oliver Pye, 'Agrarian Marxism and the Proletariat: A Palm Oil Manifesto', *The Journal of Peasant Studies* (2019), online first, 8–10.

[37] Pye, 'Commodifying', 224.

[38] Gaveau et al., 'Rapid', 8. Governments are often shareholders in these companies, it should be noted.

Southeast Asia has seen an epic resurgence of the plantation in the early twenty-first century, a unit from the colonial era coming back to grab land and squeeze out other forms of life.[39] The integrity of bats would be the least of the owners' concerns.

Hence the region is the theatre of an undeclared war on flying foxes, the largest megabat with a wingspan of nearly two metres, normally congregating in noisy communal camps in mangroves, swamps and rainforests. Deforestation rips up their habitat and stresses them out.[40] Palm oil is not the sole commodity to blame, of course; in the case of the Nipah virus, it was commercial pig farming that drove wedges deep into the woods of fruit bats and forced them to visit the farms. Deforestation-induced stress has been reported for a bat species in a northern area of Thailand likewise beset by plantations and infrastructure development, although not quite on the scale of Malaysia.[41] The number of high-resolution studies remains low at the time of this writing, but chiropterologists recognise the broad picture, and it is not confined to Southeast Asia.[42]

The Cockpit Country in the heart of Jamaica is a karst landscape, formed through the dissolution of limestone rocks, taking the shape of many hundreds of mountain peaks around deep

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[39] Derek Byerlee, 'The Fall and Rise Again of Plantations in Tropical Asia: History Repeated?', *Land* 3 (2014): 574–97.

[40] H. E. Field, 'Bats and Emerging Zoonoses: Henipaviruses and SARS', *Zoonoses and Public Health* 56 (2009): 278–84.

[41] David Costantini, Gábor Á. Czirják, Paco Bustamante et al., 'Impacts of Land Use on an Insectivorous Tropical Bat: The Importance of Mercury, Physio-Immunology and Trophic Position', *Science of the Total Environment* 671 (2019): 1077–85; cf. K. Waiyasusri, S. Yumuang & S. Chotpantarat, 'Monitoring and Predicting Land Use Changes in the Huai Tap Salao Watershed Area, Uthaithani Province, Thailand, Using the CLUE-s Model', *Environmental Earth Sciences* 75 (2016): 1–16.

[42] The broad picture: e.g. Kingston, 'Response', 180; Meyer et al., 'Responses', 64; Field, 'Bats', 282.

valleys that continue underground in uncountable caves.[43] As rich in shelter, the forest is in food: wild yam and banana and guava trees, cotton, Santa Maria, guango. This is a haven for more than a dozen endemic bat species. During the colonial era, it was also a refuge for slaves on the run from plantations, or maroons, who fought the British from within the nearly impenetrable fastness. According to oral traditions, the maroons would replenish their muskets with gunpowder concocted out of bat guano from the caves, so rich in nitrogen as to be explosive. Maroon communities descending from the runaway slaves still inhabit the villages around the forest and act as its custodians, but they face a threat: there is bauxite in the ground. The Canadian mining company Noranda has been chafing at the bit for years, waiting for the go-ahead to enter and commence strip mining, but the government has so far hesitated. The fate of Cockpit Country is the central environmental battle of Jamaica. It attracts a steady stream of protests from maroons and their allies and counter-protests from Noranda's employees and is invoked every time there is a climate rally, as during the school strikes of 2019.[44] When the Covid-19 pandemic reached Jamaica, calls for the elimination of bats prompted one of the environmental NGOs most involved in the struggle to instead call out: 'Leave the bats alone!' – another reason not to unfetter Noranda.[45] How many more interfaces of this kind are in the offing? Nobody knows. The points of collision between bats and capitalists around the equator remain to be mapped.

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[43] This paragraph draws on field observations by the author in 2017.

[44] See e.g. Esther Figueroa, 'Cockpit Country Still Under Threat From Bauxite Mining', *Jamaica Gleaner*, jamaica-gleaner.com, 28 July 2019; Paul Clarke & Andrew Williams, 'Noranda: We All Want to Protect Cockpit Country', *Jamaica Gleaner*, 18 September 2019; *Loop Jamaica*, 'Entertainers Lead Proposed to Parliament About Cockpit Country', loopjamaica.com, 18 September 2019; and the wonderful short film by Esther Figueroa, the Jamaican film-maker and activist documenting the struggle around the Cockpit Country, '#ClimateStrike_SaveCockpitCountry', YouTube, 3 October 2019.

[45] The Jamaica Environment Trust in *Loop Jamaica*, 'Coronavirus: Leave the Bats Alone – JET', 10 April 2020.

But one scientist who has begun the work is Rob Wallace, heir apparent of the venerable tradition of dialectical biology in the age of zoonotic spillover. He has honed in on Ebola. This virus, of another family than corona, had been slumbering in West Africa for a long time, riding on fruit bats, skipping out of the rainforest to infect a village or two, the outbreaks documented since 1976 coming to two dozen. What happened in 2014 was something altogether different. In an outbreak more than forty times larger than any before it, Ebola vaulted into a proto-pandemic phase, striking out from Guinea to hit Liberia, Sierra Leone, Nigeria and Senegal, killing more than half of infected patients – fever, diarrhoea, profuse bleeding inside and out of the body – and leaving corpses on the streets of capital cities.[46] What accounted for this phase change? It must be some 'non-virological' development, not internal to the pathogen or its host.[47] In the half-decade before the disaster, the World Bank had identified the forested zones of the region as 'one of the largest underused agricultural reserves in the world', and the government of Guinea set to work handing it over to one branch of agribusiness: palm oil. The plantation boom arrived here too, promoted by companies from countries such as the US, the UK, Malaysia and Indonesia, expropriating swaths of land for the commodity. And naturally, fruit bats were kicked out of old

[46] David W. Redding, Peter M. Atkinson, Andrew A. Cunningham et al., 'Impacts of Environmental and Socio-Economic Factors of Emergence and Epidemic Potential of Ebola in Africa', *Nature Communications* 10 (2019), 2; Derek Gatherer, 'The Unprecedented Scale of the West African Ebola Virus Disease Outbreak Is Due to Environmental and Sociological Factors, Not Special Attributes of the Currently Circulating Strain of the Virus', *BMJ-Evidence Based Medicine* 20 (2015): 28; Robert G. Wallace, Marius Gilbert, Rodrick Wallace et al., 'Did Ebola Emerge in West Africa by a Policy-Driven Phase Change in Agroecology?', in Robert G. Wallace & Rodrick Wallace (eds.), *Neoliberal Ebola: Modeling Disease Emergence From Finance to Forest and Farm* (Cham: Springer, 2016), 1, 4; Wallace, *Big*, 326.

[47] Gatherer, 'The Unprecedented'. The factors proposed by this author, including 'funerary practices', appear almost flippant alongside Wallace's rigorous investigations. But cf. also Daniel G. Bausch & Lara Schwarz, 'Outbreak of Ebola Virus Disease in Guinea: Where Ecology Meets Economy', *PLOS Neglected Tropical Diseases* 8 (2014): 1–5.

haunts and instead swarmed around the palm groves. By denuding old-growth forests, the enterprises did away with the 'friction, which typically keeps the virus from lining up enough transmission', the dilution effect inverted into streamlining. None of the natural scientists we have referred to up to this point are Marxists (although one cannot, of course, rule out that they are closet Marxists), but it takes a card-carrying Marxist like Wallace to draw out the implications: 'opening the forests to global circuits of capital' is in itself '*a primary cause*' of all this sickness.[48] It is unrestrained capital accumulation that so violently shakes the tree where bats and other animals live. Out falls a drizzle of viruses.

Ecologically unequal and pathological exchange

There is another implication too: causation is not local. 'If landscapes, and by extension their associated pathogens, are globalized by circuits of capital, the source of a disease may be more than merely the country in which the pathogen first appeared.'[49] The impetus for mining even more bauxite in Jamaica comes from elsewhere. The material is not taken up to feed the children of Kingston. It is foreign capital investing in it, shipping it off to aluminium plants in the US and profiting from it, in the very picture of scorched-earth extractivism, leaving behind gaping red wounds in the landscape and asthma for the kids. The palm oil is not meant for the households of

[48] Wallace et al., 'Did Ebola', 2–9; Wallace, *Big*, 328–30 (World Bank quoted in Wallace *Big*, 328; the other quotations from 333, 327, 330, with emphasis added). Note that the article included in *Big* was originally published as Robert G. Wallace, Richard Kock, Luke Bergmann et al., 'Did Neoliberalizing West African Forests Produce a New Niche for Ebola?', *International Journal of Health Services* 46 (2016): 149–65. Another study independently reached essentially the same conclusion about the role of deforestation: Maria Cristina Rulli, Monia Santini, David T. S. Hayman & Paolo D'Odorico, 'The Nexus Between Forest Fragmentation in Africa and Ebola Virus Disease Outbreaks', *Nature Scientific Reports* 7 (2016): 1–8.

[49] Wallace, *Big*, 331.

Malaysia. It is exported to cosmetic, chemical, food, livestock, energy industries around the world, and the trend is the same for the other three commodities felling the tropics: beef, soybean, timber flow out of their countries of origin.[50] To make sense of this, scholars have borrowed the concept of 'teleconnections' from meteorology – a rise in the atmospheric pressure in the Malay Archipelago sets off an El Niño that touches off downpours over Peru and dry spells in Botswana – and applied it to trade flows.[51] Remote demand for products grown in the tropics now drives deforestation in the aggregate.[52]

This should not come as a surprise, as late capitalist globalisation is defined by spatial separation between production and consumption: what is bought in one place comes from some unfamiliar antipode. Causation must then levitate above the ground, but it doesn't move evenly. The atmospheric pressure of demand still rises in the North. If one calculates the amount of land embodied in traded goods – the land required to grow the commodities, feed them, mine them, process and assemble them – one finds Europe to be an epicentre of teleconnections. EU countries source more than half of their land-based consumption from other parts of the world, the share exceeding four fifths for Germany. Japan (92 per cent) and the US (33) are not far behind

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[50] Pye, 'Commodifying', 221; Henders et al., 'Trading'; Meyfroidt et al., 'Multiple'.

[51] E.g. Yang Yu, Kuishuang Feng & Klaus Hubacek, 'Tele-Connecting Local Consumption to Global Land Use', *Global Environmental Change* 23 (2013): 1178–86. One version is 'tele-coupling': Christina Prell, Laixiang Sun, Kuishuang Feng et al., 'Uncovering the Spatially Distant Feedback Loops of Global Trade: A Network and Input-Output Approach', *Science of the Total Environment* 586 (2017): 401–8.

[52] Ruth S. DeFries, Thomas Rudel, Maria Uriarte & Matthew Hansen, 'Deforestation Driven by Urban Population Growth and Agricultural Trade in the Twenty-First Century', *Nature Geoscience* 3 (2010): 178–81. Cf. e.g. Eric F. Lambin & Patrick Meyfroidt, 'Global Land Use Change, Economic Globalization, and the Looming Land Scarcity', *PNAS* 108 (2011): 3465–72.

in total appropriation of embodied land.[53] These are not trivial flows. Just how much land is shuffled northwards is indicated by the calculation that in 2007, the EU had a net import of goods embodying land *as large as the entire surface area of India*; it will have grown since then.[54] Put differently, every year the EU sucks in a volume of land at least equalling the size of India, over and above the land embodied in its export and the import that matches it. The trade balance might show something else; it can record a surplus of exports or a small deficit, as counted in euros or dollars. But counted in *actual land*, the EU gobbles up enormous quantities offered up by others through the mediation of the market, with no balance in sight. The Union epitomises the process known as ecologically unequal exchange: transactions that might seem fair on the monetary surface, but allow rich countries to absorb biophysical resources from the poor and drain their natural endowments.

These include forests. With all the rigour of quantitative methods, a body of literature has demonstrated that if developing countries rely on export to developed partners, they tend to cut down their own forests faster to serve up the commodities in demand. Such relations would not, of course, have come about if it weren't for colonialism. The legacy is kept alive by means including structural adjustment programmes, debt repayment, investment from multinational corporations and projects supported by state agencies such as the US Export-Import Bank, all of which have been shown to speed up forest loss. Out of the clearings the commodities can then come gushing: the American appetite for hamburger is satisfied from pastures carved out of the Amazon. The import of coffee to the North presupposes deforestation in the tropical belt. Chocolate, consumed in the most tremendous quantities in Switzerland, Germany and Austria and supplied by a

[53] Yu et al., 'Tele-Connecting'. On Europe as epicentre, see also the telling map in Prell et al., 'Uncovering', 405.

[54] Christian Dorninger & Alf Hornborg, 'Can EEMRIO Analyses Establish the Occurrence of Ecologically Unequal Exchange?', *Ecological Economics* 119 (2015), 417.

mirroring top trio of Ivory Coast, Ghana and Indonesia, comes from cocoa trees grown where wild forests once stood: and the shopping list goes on.[55]

Far from the shelves of supermarkets, on latitudes closer to the equator, this translates into the ravaging of local biodiversity. By purchasing commodities from the tropics, rich importers can offload the impacts on animals and plants from their own lands to those that, incidentally, house a greater richness of species. It has taken the science some time to catch up and connect the dots, but, in 2012, one pathbreaking study derived one third of all existential threats to animal species straight from the sale of goods like coffee, beef, tea, sugar and palm oil to countries of the North. The top seven importers of biodiversity threats were – always on top? – the US, Japan, Germany, France, UK, Italy and Spain. The top seven exporters of these same threats – that is, countries from which biodiversity was bled white – were Indonesia, Madagascar, Papua New Guinea,

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[55] E.g. Andrew K. Jorgenson, 'Unequal Ecological Exchange and Environmental Degradation: A Theoretical Proposition and Cross-National Study of Deforestation, 1990–2000', *Rural Sociology* 71 (2006): 685–712; John M. Shandra, Christopher Leckband & Bruce London, 'Ecologically Unequal Exchange and Deforestation: A Cross-National Analysis of Forestry Export Flows', *Organization & Environment* 22 (2009): 293–310; Andrew K. Jorgensen, Christopher Dick & Kelly Austin, 'The Vertical Flow of Primary Sector Exports and Deforestation in Less-Developed Countries: A Test of Ecologically Unequal Exchange Theory', *Society and Natural Resources* 23 (2010): 888–97; Andrew K. Jorgenson, 'World-Economic Integration, Supply Depots, and Environmental Degradation: A Study of Ecologically Unequal Exchange, Foreign Investment Dependence, and Deforestation in Less Developed Countries', *Critical Sociology* 36 (2010): 453–77; Kelly Austin, 'The "Hamburger Connection" as Ecologically Unequal Exchange: A Cross-National Investigation of Beef Exports and Deforestation in Less-Developed Countries', *Rural Sociology* 75 (2010): 270–99; Kelly Austin, 'Coffee Exports as Ecological, Social, and Physical Unequal Exchange: A Cross-National Investigation of the Java Trade', *International Journal of Comparative Sociology* 53 (2012): 155–80; Mark D. Noble, 'Chocolate and the Consumption of Forests: A Cross-National Examination of Ecologically Unequal Exchange in Cocoa Exports', *Journal of World-Systems Research* 23 (2017): 236–68; Michael Restivo, John M. Shandra & Jamie M. Sommer, 'Exporting Forest Loss? A Cross-National Analysis of the United States Export-Import Bank Financing in Low- and Middle-Income Nations', *Journal of Environment and Development* 29 (2020): 245–69.

Malaysia, the Philippines, Sri Lanka and Thailand.[56] The flow is vertical, the space of species blowing to the North.

A suite of studies confirming the basic pattern has followed, some putting the share of extinction threats to northbound exports much higher – up to 60 per cent – others staying closer to one third.[57] One critical nuance has been added. Measured per capita, the variations in consumptive claims on biodiversity are even more skewed, with rich but sparsely populated countries like Canada and Finland shooting up to the top: one typical Finn will inflict species losses through trade far above the global average. One Chinese or Indian still treads lightly.[58] The next step, of course, would be to break these numbers down further into income brackets and study

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[56] M. Lenzen, D. Moran, K. Kanemoto et al., 'International Trade Drives Biodiversity Threats in Developing Nations', *Nature* 486 (2012): 109–12. Cf. e.g. Sabine Henders, Madelene Ostwald, Vilhelm Verendel & Pierre Ibisch, 'Do National Strategies Under the UN Biodiversity and Climate Conventions Address Agricultural Commodity Consumption as Deforestation Driver?', *Land Use Policy* 70 (2018): 580–90.

[57] E.g. Franz Essl, Marten Winter & Petr Pysek, 'Trade Threat Could Be Even More Dire', *Nature* 487 (2012): 39; Daniel Moran & Keiichiro Kanemoto, 'Identifying Species Threat Hotspots From Global Supply Chains', *Nature Ecology and Evolution* 1 (2017): 1–5; Francseca Verones, Daniel Moran, Konstantin Stadler et al., 'Resource Footprints and Their Ecosystem Consequences', *Nature Scientific Reports* 7 (2017): 1–11; Thomas Wiedmann & Manfred Lenzen, 'Environmental and Social Footprints of International Trade', *Nature Geoscience* 11 (2018): 314–21; Alexandra Marques, Inês S. Martins, Thomas Kastner et al., 'Increasing Impacts of Land Use on Biodiversity and Carbon Sequestration Driven by Population and Economic Growth', *Nature Ecology and Evolution* 3 (2019): 628–37; Abhishek Chaudhary & Thomas M. Brooks, 'National Consumption and Global Trade Impacts on Biodiversity', *World Development* 121 (2019): 178–87. 60 per cent: Widmann & Lenzen, 'Environmental', 316; closer to one third: Marques et al, 'Increasing'; Chaudhary & Brooks, 'National', 178.

[58] Harry C. Wilting, Aafke M. Schipper, Michel Bakkenes et al., 'Quantifying Biodiversity Losses Due to Human Consumption: A Global-Scale Footprint Analysis', *Environmental Science and Technology* 51 (2017): 3298–3306 (quotation from 3304).

how *classes* of Canadians and Finns, Chinese and Indians exert their respective pressure; but the findings can be pre-empted virtually by tautology. To be very rich means to have all the money in the world to eat tropical land. Indeed, statistically, 'with an increase in affluence biodiversity losses due to import increase faster than domestic losses' – that is, the richer one is, the more likely to gobble up the space of other species from a distance. Any bad taste is unlikely to survive the stage of packaging.

While ecologically unequal exchange has been traditionally arraigned as unethical for causing undue harm to the lands of the periphery, we can now, following Wallace's lead, take one step further: it is a deep driver of deforestation, hence of biodiversity loss, hence of zoonotic spillover. Some bats and other hosts will be sucked into those trade winds. The research is still in its infancy, as we have seen, but, in early March 2020, *Nature Communications* published a model study that followed the link all the way from shelf to sickbed in one case: malaria, one of those beneath-the-radar diseases, affecting some 230 million and killing 400,000 per year, the vast majority in rainforest biomes. Deforestation is a boost for the mosquito vectors. More sunlight reaches the soil where the larvae develop; when biodiversity retreats, fewer animals prey on them. Nigeria suffers most from malaria due to deforestation. It is largely caused by the export of timber and cocoa. Such commodities end up in the north: the consumers with the greatest malaria footprint are the cocoa-guzzling Dutch and Belgians, Swiss and Germans. 'In this unequal value chain, ecosystem degradation and malaria risk are borne by low-income producers' – or, in plainer terms: the Europeans get the chocolate and the profits, the Africans the mosquitos.[59]

[59] Leonardo Suveges Moreira Chaves, Jacob Fry, Arunima Malik et al., 'Global Consumption and International Trade in Deforestation-Associated Commodities Could Influence Malaria Risk', *Nature Communications* 11 (2020): 1–10 (quotation from 5).

Bat-borne viruses travel farther with a greater capacity for blowback, but the drivers are broadly similar. Indeed, if one adds investment flows, one ends up with an even more pronounced version of Wallace's upside-down map: the real hotspots of disease lie in places like New York and London and Hong Kong.[60] The forces reaching out to forests and pulling out pathogens are nowhere as strong as in the central nodes of capital.

[60] Robert G. Wallace, Luke Bergmann, Richard Kock et al., 'The Dawn of Structural One Health: A New Science Tracking Disease Emergence Among the Circuits of Capital', *Social Science and Medicine* 129 (2015), 70; Wallace et al., *Clear-Cutting*, 32. The factor of investment, or capital accumulation as such, has been integrated in at least one statistical study of land appropriation, unsurprisingly showing it to be an even larger phenomenon than if only trade flows are measured: Luke Bergmann & Mollie Holmberg, 'Land in Motion', *Annals of the American Association of Geographers* 106 (2016): 932–56.