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# VIR OLOGY

Viruses are usually only noticed when something goes wrong. Within the space of a few weeks in March 2020, an emergent virus burst the bubble of modernity. We were on a trajectory of growth, seemingly without limits. But, then an invisible infectious agent disrupted our collective dreams and schemes. Hazy clouds of coronavirus particles, with unknown properties, suddenly began haunting our every movement. Nervous energy interrupted economic, commercial, social, and cultural systems in all parts of the planet. Airline fleets were grounded. Carbon emissions were radically reduced, even if just for a short period of time.<sup>1</sup> Industrial supply chains struggled to meet the demands for food, medical equipment, even toilet paper. The new coronavirus strain diminished human agency on a planetary scale.

Long before the pandemic, modern philosophers argued that human worlds existed outside the realm of material objects and ecological relationships. Martin Heidegger is famous for pushing this argument with a three-part thesis: “The stone (material object) is *worldless*; the animal is *poor in world*; man is *world-forming*.”<sup>2</sup> Similar claims about the exceptional capacities of the human were taken up a decade ago by Peter Sloterdijk, the contemporary German philosopher who styles himself as the “second coming” of Heidegger. Sloterdijk wrote a series of playful books about spheres, bubbles, foams, and globes while working hard to defend the dualistic thinking that underpins modernity: he argued that humans alone move among worlds. In his own words, Sloterdijk suggested that humans are “ontological amphibians”, while animals “move around in an ontological cage”.<sup>3</sup> These philosophers were blind to the world-forming capacities of animals, as well as the multitude of unseen agents lurking at the edges of the known world.

Perhaps you also think that you live in a bubble – alone in an apartment, a self-contained unit, where there are few occasions for social and ecological interactions. Think again. You live within the virosphere – the vast but poorly understood

universe of viruses. With every breath you inhale around six litres of air along with thousands or even millions of viral particles. Viruses are also entering your body each time you take a bite of food, or a drink of water. All told, you encounter around a billion viral particles everyday.<sup>4</sup> Some of these viruses are capable of infecting human cells, but many belong to the insects, fungi, animals, and bacteria that live within us, or near us. These viruses are world-forming as well as world-destroying.

Viruses have been found in seemingly inhospitable locations like deep-sea vents, glacial ice, as well as extremely hot and acidic springs. Genetic diversity on planet earth is a story of viral diversity. Viruses are the most abundant life form that has been described, and more than 99.9% of their species remains unstudied. Simply put, viruses are winners in the game of life.<sup>5</sup> Cultural theorists have recognised the importance of these infectious agents ever since Deleuze and Guattari suggested that “our viruses make us form a rhizome with other animals”.<sup>6</sup> But, in recent years cultural theorists have not kept up with the scientific initiatives that have started to map the vast unknown realms of the virosphere.

The world-forming capacity of viruses has been well studied in the ocean ecosystems of coral reefs and plankton. Viruses that infect bacteria, and other microorganisms, are called “phages”. As marine microorganisms dynamically interact with the environment, they use phages to trade beneficial genes. Some phages help their hosts enhance photosynthesis. Other phages give their hosts new tricks as they hunt for phosphorous, a key nutrient that is scarce in many oceans. Marine viruses also promote overall diversity in these ecosystems. If any one member of the plankton community becomes too abundant, they tend to be culled by viral infections. This principle is known to ecologists as “kill the winner”.<sup>7</sup>

Marine microbes, like cyanobacteria, play a major role in the global carbon cycle – pulling greenhouse gasses out of the atmosphere and releasing oxygen. Since viruses control the population dynamics of these microbes, they also are tremen-

dously important to life on earth. One article from the primary literature suggests: “We live in a microbial driven world that only exists because Bacteria and Archaea tempered the previously hostile environment on early Earth”.<sup>8</sup> Some marine viruses kill small creatures at the surface of the ocean, which then fall through the water column like snow, sequestering carbon under layers of sediment at the bottom of the ocean. Other phages release carbon at the ocean’s surface, when they cause their hosts to explode through a process called lysis.<sup>9</sup> An article in the *Annual Review of Virology* builds on this body of knowledge about the role of viruses in the global carbon cycle to suggest: phages run the world.<sup>10</sup>

James Lovelock suggested that we think about earth as Gaia, that is “an entity comprising a whole planet and having the powerful capacity to regulate its climate and chemical composition”.<sup>11</sup> His evidence for the existence of Gaia came from thermodynamics – relating to heat, radiation, and the circulation of greenhouse gasses on a planetary scale – as well as from cybernetics, the field dealing with self-regulating systems that maintain homeostasis. Gaia seemed to be a benevolent mother whose health, well-being, and regulatory processes needed protecting.

Over the past forty years, since the time of the initial Gaia hypothesis, this earth-mother has not been protected. Isabelle Stengers suggests that we move away from the image of Gaia as a caring mother, and instead think of her as “the fearsome one” – as she was once addressed by Greek peasants. In this frame of mind, Gaia tolerates humanity, but does not have infinite patience. If we anthropomorphise the earth as a mother, she might be understood as an irritable one – who should not be offended. If she is irritated, in the words of Stengers, “the response that Gaia risks giving might well be without any measure in relation to what we have done, a bit like shrugging of the shoulder provoked when one is briefly touched by a midge”.<sup>12</sup>

One could interpret the emergence of the coronavirus pandemic as Gaia’s self-regulatory processes kicking in, ac-

ording to the principle of “kill the winner”. But, the personification of Gaia assumes that there is a unified whole, a meta-system that governs other systems, to borrow the parlance of Mark Zuckerberg. Rather than worry about offending Gaia, I find myself meditating on the ways that a multitude of parallel processes in the unseen and unknown realms of the virosphere are being perturbed by human activities.

As carbon dioxide accumulates in the atmosphere the oceans are acidifying. The basic chemistry of seawater is changing as it absorbs this greenhouse gas. Rapid changes to the planetary oceans are poorly understood, but could have far-reaching consequences for the food-web of plankton ecosystems and the global carbon cycle. Dynamic interactions among viruses and marine microorganisms could suddenly shift, perturbing the conditions that sustain human life on Earth. Instead of self-regulating feedback loops, we could soon be faced with a runaway system – where anthropogenic, virogenic, planktonic, geochemical, and thermodynamic forces begin to reverberate with one another and accelerate. We are looking at a future with serious unknown unknowns. MIT scientists recently reported “significant uncertainty” in previous calculations about marine processes that take up carbon dioxide from the atmosphere and transport it deep into the ocean, where it can be sequestered for centuries. Earlier climate models suggested we could avoid extreme planetary catastrophes if we curbed emissions by 2040 to stay within 1.5 degrees of warming, in line with the Paris Agreement. But, new calculations at MIT suggest that previous models of carbon sequestration and marine snow may be wrong. Earlier calculations may be off by as much as five years, meaning that we only have until 2035 to rein in air pollution.<sup>13</sup>

Marine viruses are mostly indifferent to us. Perhaps, though, these infectious agents can mount a collective, somewhat coordinated, and unruly response to the ways that human activities are changing planetary chemical and ecological cycles. But, they will not deliver climate justice. They will not

be the righters of wrongs. Wealthy people are in the best position to erect architectures and infrastructures that may offer temporary protection from hostile planetary conditions – bubbles that give inhabitants the illusion that they can still keep the environment at a distance, at least for a little while longer.<sup>14</sup> Even in the face of a world destroying disaster, some would likely survive. But in a truly nightmarish scenario, inhuman viral, geochemical, and thermodynamic forces could eliminate the conditions of life for most animals and plants. The meek – the fungi, the lichen, the protists, the cyanobacteria, and their viral companion species – could inherit the earth.

Viruses often inspire fear. The history of virology has been driven by anxiety about disease and death.<sup>15</sup> Traditionally, virologists worked to identify and isolate the agents driving infectious diseases. In the face of the vast unknown of the virosphere, perhaps it is also easy to be afraid of forces that we can barely understand. Ecological interactions with mind-boggling complexity could suddenly shift, destroying our life support systems. The unruly realm of viral biodiversity could generate a new pandemic at any moment. But, what if we instead approached the virosphere with curiosity and wonder. Is it possible to empathise with a virus?

Merry Youle, author of *Thinking Like a Phage*, insists: “Outside our normal vision, the phage multitude is always there – an ancient, dynamic, bubbling, creative force that underpins all life on earth”.<sup>16</sup> In describing the ways that phages “think” and “dance”, Youle invites us to imagine how these viruses move through three-dimensional space.

Conventionally phages are drawn to look like spiders, with spindly tail fibres (like spider legs), a long tail sheath, and a capsid head (like a bulging spider abdomen). The movie *Matrix Revolutions* features phage-like “Sentinels”, which patrol the sewers and passageways of dead human cities in search of hovercraft or wandering people. In the words of Trinity, the

Zion operative who is Neo's lover, a Sentinel is a "killing machine designed for one thing. Search and destroy".<sup>17</sup> Once the Sentinel find a person, or a human ship, they wrap their legs around their prey in a lethal embrace. While violent imagery continues to dominate the depiction of viruses in popular culture and the scientific literature, Youle describes the movements of phages with more careful and delicate terms:

The iconic image of a phage seen on T-shirts and coffee mugs is that of a virion tumbling through the milieu, its six "claws" outstretched, poised for a deadly encounter with a hapless bacteria. However, such images can be misleading. Consider a more restrained possibility: a phage holding most of its tail fibres close to its tail or head, gingerly extending just one at a time to test the waters.<sup>18</sup>

While on the prowl, some phages extend their individual tail fibres, one at a time, feeling around for bacterial prey. When a phage contacts a potential host, it walks along the cell surface like a six-legged dancer lightly balancing on only one leg at a time. If it finds an appropriate receptor it binds with the host cell, and injects genetic material inside.<sup>19</sup> Some phages take over bacteria, to reproduce quickly at their host's expense, to explode in lysis. Many others – perhaps the majority – adopt longer-term symbiotic strategies.<sup>20</sup> These viruses integrate their genetic material into the host's chromosome. Some symbiotic viruses contribute to the formation of new micro-worlds by giving their bacterial hosts an ability to form new external protective layers of biofilm. Others, when they act together on a massive scale, help sustain planetary ecologies as they provide their hosts with new pathways to sequester phosphorous, or for more efficient photosynthesis.

Viruses that infect people generally look more like spherical balls, with bumps or spikes, instead of spider-like phages with delicate legs or claws. Many philosophers have debated the status of these viral particles – wondering if they are truly forms of "life" or actually "non-living" material. Understanding the properties of a virus by looking at the viral particle in isolation is a bit like trying to understand a tree by carefully

examining a seed. Sidestepping debates about life and non-life, John Dupré and Stephan Guttinger suggest that viruses "should be seen as processes rather than things, or substances". On a molecular level, viruses are "living processes" that interact with other living systems and processes with "inter-connected and collaborating segments of many genetically distinct lineages". If we understand viruses as lively processes, that take place as viral proteins interface with the organelles inside of cells, then it is possible to develop "a relational approach to viral agency".<sup>21</sup> Thinking about these molecular relations enables us to grasp how viruses interrupt, augment, and reroute processes within host cells, while also influencing larger-scale processes in organisms, ecosystems, and even the planetary biosphere.

While many biologists and philosophers are trying to empathise with viruses, some theorists remain anxious about disease, death, and destruction. Elizabeth Povinelli equates viruses with terrorists. She sees the figure of the virus in "the waste dump, the drug-resistant bacterial infection stewed within massive salmon and poultry farms ... the person who looks just like 'we' do as she plants a bomb". In a more subtle register, Povinelli suggests: "The Virus copies, duplicates, and lies dormant even as it continually adjusts to, experiments with, and tests its circumstances". Also, the "Virus is the popular cultural figure of the zombie – Life turned to Nonlife and transformed into a new kind of species war".<sup>22</sup>

One could venture into the virosphere to search for terrorists. But terrorism is just one mode of viral politics. Lysis, the strategy of immediate viral replication followed by host death, involves "the single-minded pursuit of maximum short-term gain", in the words of Youle.<sup>23</sup> Many viruses pursue a different strategy, lysogenesis, where they reside quietly inside the host cell and pursue symbiotic possibilities. With the wild imagination of Hollywood, you could interpret the lysogenic virus as a zombie that lies dormant, ready to erupt into a new species war. But, it is important to remember that

viruses are obligate parasites – they depend on bacteria, plants, animals, and people for their own existence. A parasitic guest that goes to war with its host quickly finds itself without a place to rest, and must move on.<sup>24</sup>

Viruses are us. Around half of our genome is “junk DNA”, traces of ancient viral infections as well as new insertions from retroviruses and jumping genes.<sup>25</sup> The ancient viruses we carry move around in our genomes during the course of a normal human life. Most often these jumping genes – called transposable elements – just bounce around inside of the nucleus of individual cells, finding new places to insert themselves in a chromosome.<sup>26</sup> Mobile viral elements are unknown unknowns that lurk within our own bodies and selves. Little is known about how they impact the structure and function of our cells, our overall health and well-being, or our mutant, monstrous, and evolutionary potentialities.

Most ancient viruses appear to be “neutral”, as best as biologists can tell. A few transposable elements have been linked to diseases, like cancer.<sup>27</sup> Other endogenous retroviruses lurking within our bodies are activated when we are infected by other viruses – like dengue, herpes, influenza. These ancient viruses can protect us – their hosts – from new, potentially pathogenic, infections.<sup>28</sup> Some old viruses, lurking within our genomes, appear to be reactivated at random. They can produce little viral particles that travel around our bodies, from cell to cell.<sup>29</sup> There is growing evidence that genes occasionally jump into the body of another person, or even into other creatures that belong to different species, kingdoms, and domains.<sup>30</sup>

Our bodies are home to a dynamic ecosystem of viruses that stimulate our immune systems, maintain an equilibrium of bacteria in our guts, and protect us from diseases. One beneficial virus that has been relatively well studied, known as *Pegivirus*, apparently offers benefits to people who are infected with HIV. *Pegivirus* produces changes in human cells that

make them resistant to HIV infection and increases the overall likelihood that someone will survive from AIDS. As we learn more about “good” viruses like *Pegivirus*, we might better understand some of the detrimental health impacts of modern lifestyles and hygienic practices. *Pegivirus* is only present in 1% to 5% of blood donors in places like the United States and Europe, while it is present in up to 20% of the population in developing countries.<sup>31</sup>

Viruses abound in bodily fluids and organs that were previously thought to be sterile – including the liver, kidney, blood, lymph, cerebrospinal fluid, and brain.<sup>32</sup> Of all the microbial communities in our body, the microbiome of our gut is by far the most complex, dense, and dynamic with around ten trillion bacteria and two trillion phages. Our respiratory system and our gut are coated with mucus, which is a sticky trap for microbes. On a molecular level our mucus is made up of mucins – a molecule that has an idiosyncratic structure, a molecular signature, that is distinct for each of us. Our mucins help us collect potentially beneficial phages, which have unique “decorative” proteins on their head. The capsid heads of the phages are embedded in the mucus, and their delicate legs are probing out in space – looking for bacteria that might be passing nearby. Imagine the layer of sticky and viscous mucus in your gut – as well as your sinuses and lungs – with a multitude of viral biodiversity wiggling on the surface. By cultivating and curating this lively multitude of phages, the body is indirectly managing the symbiotic and pathogenic bacteria in the gut.<sup>33</sup>

When you look too closely at the human gut it is difficult to distinguish the inside from the outside, or separate “us” from “them”. Some of the cells that line our gut – in the epithelial tissue that is covered in mucus – actively transport phages into our bodies. These cells have mucin proteins on their surface that selectively bind with phages, and then bring them into our bodies. As these viruses circulate within our bloodstream, there is a mild response from our immune system. While researchers are still working to characterise the di-

versity of these viruses, the general consensus is that the phages within us are doing more good than harm – they appear to be helping the immune system protect us from any bacteria that wander into places where they are not supposed to be.<sup>34</sup>

Little research has been conducted on the role that phages play in our central nervous system and brain. Some studies suggest that they might help our bodies identify and destroy cancers and tumour cells, as well as plaque structures associated with Alzheimer’s and Parkinson’s diseases. Since many fungi, bacteria, and animal viruses can produce changes to neurons and observable behaviour, some scientists have started to speculate about the possibilities of phage “mind control”.<sup>35</sup>

Viruses offer more evidence to Donna Haraway’s startling contention: “we have never been human”.<sup>36</sup> While scientists continue to search the human genome for DNA sequences that set us apart from other species, the abundance of evidence suggests that we share much of our genetic identity with viruses. These infectious agents link humanity with other creatures who live with us in shared multispecies worlds. We are kin with our viral relations.

“Human nature is an interspecies relationship”, according to Anna Tsing. In making this claim, Tsing was inviting us to consider how ancient humans were transformed as they developed new agricultural strategies to cultivate wheat around 12,000 years ago. New sedentary lifestyles, forms of wealth, and social hierarchy emerged as this plant domesticated us.<sup>37</sup> Holding Tsing’s ideas about domestication together with scholarship about our entanglements with other plants, animals, and microbes, prompts me to give her argument a new twist: human nature is a multispecies relationship.

Human nature has been shaped by apple trees, tulip flowers, corn plants, brewers yeast, not to mention the animals of empire – cattle, pigs, horses, and sheep – that have remade ecological communities in all parts of the world.<sup>38</sup> New forms of laboratory life – genetically modified rodents, *E. coli* bacte-

ria, and human cells in petri dishes – have enabled us to explore posthuman possibilities.<sup>39</sup> We have started to domesticate some viruses – like the vectors that deliver vaccines and gene therapies, as well as the phages that are used to insert trans-genes into synthetic bacteria. But, viruses that are still in the wild – not yet identified, isolated, and optimised – continue to shape who we are and how we move through the world.

Over the millennia human “nature” has been formed and transformed by infectious agents that have steadily disrupted the genetic makeup and bodily integrity of our ancestors with wave upon wave of infections. These waves continue to wash over the human species, even as most of us do our best to wear masks, observe quarantine protocol, and keep our vaccinations up to date. SARS-CoV-2, the virus that leads to serious COVID-19 symptoms in some patients, has transformed human lifestyles all over the planet – suddenly, and perhaps even more dramatically, than the development of agriculture 10,000 years ago.

Even as millions die from COVID worldwide, it is important to recognise that even this virus is not completely indifferent to the health and well-being of its hosts. A minority of people who are infected with the SARS-CoV-2 virus experience serious disease or death from COVID-19.<sup>40</sup> On a global scale, this coronavirus is not involved in “the single-minded pursuit of maximum short-term gain”. Instead, the virus has developed strategies that enable it to continue circulating – often undetected in asymptomatic human carriers as well as through populations of other animal species.

Some people reacted to the coronavirus pandemic with extreme biophobia – fear of the biological world. As these people tried to separate themselves from nature, some killed every living thing around them. Videos emerged from some cities in southern China showing municipal workers spraying billowing clouds of poison in local parks, as they tried to exterminate wild animals that might be viral reservoirs. In the Netherlands and Denmark millions of mink were culled on farms,

as authorities tried to stop COVID from jumping among animal species. Alongside this widespread biophobia, many people responded to the pandemic with feelings of biophilia – love for the biological world. Early in the pandemic – in April and May 2020 – pet adoptions surged worldwide, even though dogs and cats were found to be coronavirus carriers.<sup>41</sup>

Now we know that the pandemic coronavirus is promiscuous – it can infect bats and big cats as well as otters, cows, monkeys, great apes, white tailed deer, and hyenas. Lesser known animals in Asia – like pangolins (*Manis javanica*), raccoon dogs (*Nyctereutes procyonoides*), and the binturong (*Arctictis binturong*) – are also susceptible, as well as the coati mundi (*Nasua narica*), a long skinny critter with a ringed tail from Central America. According to the Centers for Disease Control and Prevention (CDC) in the United States, the risk of catching COVID from an animal is relatively low. But, animals in close contact with people are apparently at risk of catching the virus from us.<sup>42</sup>

Evidence is growing about a much more complex multi-species story of coronavirus emergence – involving multiple kinds of animals and spanning many different countries – than the initial origin story centred on Wuhan. The “lab leak” hypothesis was dismissed early in the pandemic because of genetic evidence, and experts from the WHO team concluded that the Huanan Seafood Wholesale Market was likely the site of a super-spreader event rather than the initial interspecies transmission.<sup>43</sup> Multidisciplinary research teams are racing to come up with a more definitive origin story – trying, perhaps in vain – to identify the particular animals and places involved in the pandemic outbreak. We continue to live with unknown unknowns. Dwelling in the virosphere means living with multispecies mysteries.

Symbiosis literally means “living together”, and symbiotic partners can have good, bad, or pluripotent effects on hosts.<sup>44</sup> Haraway wrote about the potential of viruses to induce symbiogenesis in her classic essay on “The Promises of

Monsters”.<sup>45</sup> She was referring to the way that AIDS activists were able to create a symbiotic relationship with HIV through alliances with journalists, politicians, pharmaceutical companies, and scientists.<sup>46</sup> Now, people who are infected with the HIV virus have a life expectancy that is very similar to normal – at least in countries where they have easy access to life saving medicines.<sup>47</sup> Medical and social innovations now enable many of us to live in an uncomfortable “symbiosis” with the coronavirus – in proximity with SARS-CoV-2, but without the need to be afraid of serious diseases or death from COVID-19.

Symbiotic relationships are often unwanted, or unescapable. Potentially pathogenic viruses – like HIV and SARS-CoV-2 – can be effectively domesticated into stable symbiotic relations. But, in thinking about viral symbiosis on the scale of communities, populations, and nations it is important to consider how power is at play in social and political realms. New symbiotic arrangements can reinforce injustice. Global health inequalities have been exacerbated in campaigns to vaccinate humanity. Even in countries where vaccines are readily available many vulnerable people – the homeless, members of Indigenous communities, asylum seekers, nursing home residents, and the incarcerated – continue to be at risk from COVID-19. But, some symbiotic relationships have the potential to disrupt medical inequality. Remember that at least one “good” virus – *Pegivirus*, which protects carriers from AIDS – seems to give disproportionate benefits to people who live in the Global South.

Even if we cannot fully grasp the multispecies mysteries of the virosphere, it is time to develop new practices for noticing viruses. As the waves of the coronavirus pandemic gradually recede in intensity, there is an opportunity to reflect on the full symbiotic potential of viruses – their good, bad, and pluripotent effects. The pandemic demonstrated that it is possible to make swift and dramatic changes to collective human behaviour to protect the vulnerable among us. We are all becoming vulnerable, as human industry, infrastructure, and



technology disturbs the atmosphere and the virosphere. Still, many institutions and politicians continue to operate like virulent parasites, with “the single-minded pursuit of maximum short-term gain”. Learning how to think like symbiotic viruses could offer a way out of contemporary planetary predicaments. It is possible to infect and disrupt dominant systems – to open up new generative fields of possibility.

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