**Host, parasite, and failure at the colony level:
COVID-19 and the US information ecosystem**

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Abstract

This review uses host-parasite interactions in nonhuman species to frame the poor US response to the SARS-CoV-2 pandemic. The co-evolutionary interaction between host and parasite results in changes to hosts that are achieved through genetic evolution but involve collective information sharing and behavioral adaptation at the colony level. Common examples are described among ants, bees, and other insects. The US defenses against SARS-CoV-2 were weakened by malformations in the information ecosystem that disrupted the dissemination of information while spreading misinformation and disinformation. Distortions arising from political corruption, and magnified by social media platforms, were especially consequential. I conclude that this failure may ultimately result in a social evolution that weakens US global dominance. On the other hand, if the crisis contributes to innovation and reform in the information ecosystem, that may contribute to a more egalitarian and democratic system for the production and dissemination of knowledge.

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1. Introduction

This discussion paper uses host-parasite interactions in nonhuman species to frame the poor US response to the SARS-CoV-2 pandemic. Parasites use host vulnerabilities, and evolve to modify the behavior of hosts for their own ends. Of particular interest are defenses at the colony level, adaptations – such as those seen among ants and bees – which I compare to the responses of different human societies to the current pandemic. Information flow is vital to host defenses against parasites, occurring at both molecular and social levels, among nonhumans and humans. The social, or colony, level is where the US was especially inept, due to its polarization, political corruption, and vulnerabilities to misinformation and disinformation. An isomorphism between nonhuman and human social response appears in the importance of information management and dissemination in colony-level defenses against parasitic infections.

2. Viral volition

Many people imagine the COVID-19 pandemic as a unilateral assault on humanity by a volitional opponent. Former US President Donald Trump frequently referred to the virus as an “invisible enemy,” which was “tough and smart” [1] and against which the country was compelled to wage war [2], a trope President Joe Biden repeated [3]. Journalist Ed Yong wrote that the virus had “humbled and humiliated the planet’s most powerful nation” [4]. This is consistent with naïve narratives of evolution in which whole species are actors in their own stories, seeking to gain advantage through adaptation over generations – an understandable but also misleading cognitive device for representing change over evolutionary time, especially in the case of viruses. There is no simple way to visualize the uncountable, genetically distinct viruses that are generating massive experimental trials at the molecular level, in which success or failure drives their evolution although they are not really alive, at least insofar as (like advanced computer viruses or cultural memes) they lack any metabolism of their own [5–8]. Viruses are volitional like molecules of water filtering

through sand under the force of gravity – they make progress, individually and collectively, without exerting the will to do so. As with the viruses penetrating computer networks, biological viruses succeed against humans by taking advantage of vulnerabilities in our individual immune systems as well as in our social behavior, such as population density, interpersonal interaction, and travel. In their evolutionary trials, viruses test their hosts at both the individual level and the colony level, finding more hospitable host environments among some groups of the species than others.

Throughout the world of biological ecosystems, viruses and other parasites co-evolve with host species, resulting in genetic changes among both host and parasite. One key pathway to success for parasites involves compelling or cajoling potential hosts to modify themselves in ways favorable to the parasite's spread. The co-evolutionary interaction between host and parasite results in changes to the host that may be defensive adaptations or humiliating capitulations, or both at once. Common examples are found among ants, bees, and other insects, as we will see. But this also includes humans who, for example, cough and sneeze when we get respiratory viruses, which is both a successful programming of host behavior by viruses as well as a useful survival reaction by individual hosts. In insects this plays out through genetics over many generations. Humans have the capacity to change our behavior systematically much more rapidly – for better or worse – within a generation. Beyond evaluating social responses in terms of success or failure to suppress the virus, we might also ask whether SARS-CoV-2 is changing human social behavior in ways that actually promote its spread, and whether the United States is an example of relative parasite victory in such a contest.

3. Host-parasite contests

As Table 1 illustrates, parasitic attacks trigger responses and defenses at both the individual and the colony (or collective) level, and at the biological and social levels. Although useful, the conceptual distinctions between these levels may be arbitrary and not firmly demarcated. Consider some non-human examples. Rabies is a virus that exists in most of the world, and manages to kill about 59,000 people per year [9] – mostly in Africa, Asia, and India – despite not being well suited to targeting humans, who are generally dead-

ends for rabies infection (not passing the virus to others). The virus benefits from variable and lengthy incubation and infectious periods (up to 6 months), which allow it spread vertically through births as well as horizontally from migration. But rabies is best known for having evolved an impressive behavioral manipulation of its hosts, causing them to become aggressive. Having infected the central nervous system (thus unlocking behavior), it then launches into “centrifugal spread to major exit portals, the salivary glands” [10]. The infected hosts, foaming at the mouth, transmit the virus to their victims through bites, resulting in new infections.

Table 1. Levels of interaction with, and adaptation to, parasitic attacks

Rabies alters individual behavior, but does not obviously change the behavior of subsequent generations of uninfected individuals, or of groups of individuals, maybe because it doesn’t threaten whole populations. However, many species of arthropods have evolved in conjunction with highly customized species of fungi in the genus cordyceps, mostly in jungles [11]. In one chilling scenario, infected leaf cutter ants abandon their work assignments and instead climb upward, before latching onto a plant in a death grip that lasts for several weeks, during which time a stalk grows from their heads and explodes with new spores. (The process has been popularized through videos such as one from the BBC [12].) Such phenotypic manipulation by parasites, “causing infected hosts to act in ways that benefit the parasite” [13], also include the crickets (*Nemobius sylvestris*) who are driven to seek water after being infected by hairworms (*Paragordius tricuspidatus*) that use the hosts both as a food source and then as transportation back to the water, where they extrude from the cricket and breed.

These are examples of one type of what Richard Dawkins' called the "extended phenotype," which entails "parasite genomes controlling host behavior" [14]. Natural selection of gene modifications among the parasites is based on changes achieved in the hosts' behavior or gene expression [15]. Although both organisms evolve together, the relationship is usually one-sided: "the parasite's genes almost always evolve faster and tend to call the shots, whereas the host is usually restricted to damage limitation" [16].

Although such relationships are not symbiotic, changes made to limit damage from parasites may have other benefits for hosts, involving evolved collective action that sometimes appears altruistic at the individual level. One well known example is the practice of social grooming (or allogrooming), which reduces infection by parasites (such as lice and ticks) [17], in addition to its social functions [18]. The social benefits must be balanced with the costs in terms of infection risk incurred from living in groups [19].

Beyond individual cooperation, the social immunity achieved by many insect species involves more extensive, multigenerational cooperation to protect the group from infection, using behavioral and physiological means, and requiring the "complex integration of information" to accomplish [20]. Evolutionary selection at the level of the colony feeds back through the genomes of individuals in the species, including those who experience no individual (reproductive) benefit from their role in collective adaptation [21].

Many insect species have evolved such "social immunity" [22]. Ants in particular have elaborate defense mechanisms against cordyceps [23]. They limit the number of foragers sent out from the colony. They avoid eating infected corpses. Their territorial defenses help prevent infection from other colonies. They dump infected bodies separately. They groom each other to remove spores. They socially isolate garbage workers. Other cases of social immunity include the practice of "social fevers" among honey bees, in which the colony gathers to raise its collective temperature to ward off a colonial infection [24]; and the secretion of antimicrobial chemicals by paper wasps [25], termites [26], and bark beetles [27], which involve expending energy for the protection of future generations. (Paradoxically, infectious microbes may *also* display social immunity, defined more broadly. For example, some bacteria acquire antibiotic resistance socially, and by modifying their host medium improve the survival of others that are not themselves resistant [28].)

As noted, the battle for behavioral control within host species is unbalanced, playing out over generations, with parasites having shorter generations and evolving more quickly [29]. This is painfully apparent with regard to humans and the viruses they host. If this is a series of wars, then successful adaptations by human are not victories but temporary respites. If the tendency to cough when humans get a respiratory infection enhances *individual* survival, being a *species* that coughs also makes us attractive for future invasions by viruses that cause respiratory infections. Human physiology evolves slowly against a constant stream of newly mutated viruses. Our social response, by comparison, is much nimbler – for better or worse. In short, resistance to parasitic attack is a collective and multigenerational affair in addition to an individual struggle for survival, and the lines between categories of interaction are not rigidly fixed.

4. SARS-CoV-2 in the USA

Among respiratory viruses, SARS-CoV-2 has a disease course well-suited to promoting human transmission, especially its relatively long incubation period (which facilitates infection by travelers), a viral shedding peak that coincides with symptom onset (which makes detecting contagious cases difficult) [30], and transmission by asymptomatic (or presymptomatic) carriers [31]. The last of these – especially among young adults – has presented a formidable challenge for public health messaging, which seeks to motivate people with no symptoms and relatively low risk for serious disease to comply with costly behavioral changes for the benefit of others [32].

Although COVID-19 has been a global pandemic, it has taken a unique course in the United States, where transmission and death rates at the national level surged ahead of peer-income countries in the spring of 2020, and ended the year with cumulative per-capita confirmed infection rates 2.4-times the average for countries with incomes of \$30,000 or higher per person (Figure 1).

Figure 1. COVID-19 confirmed new infection rates per capita in countries with \$30,000 (PPP) or higher per capita annual income, by date: March 2020 through January 2021. Countries shown (population 12 million+) include Australia, Canada, France, Germany, Italy, Japan, Malaysia, Netherlands, Poland, Saudi Arabia, South Korea, Spain, USA, United Kingdom. Countries not shown ($N=33$) are included in Others. Data from the John Hopkins University COVID-19 dashboard and the World Bank.

Some distinctive features of the US as a host environment are worth noting. Because the virus is transmitted through personal contact, the proximate cause of SARS-CoV-2 transmission is the failure to maintain adequate physical or spatial separation between infected and uninfected people. Within a community, infection occurs when infected people move around without staying a safe distance from others [33], or if there are not adequate barriers between them (principally masks) [34]. In the US, this occurred on a large scale in nursing facilities [35], some kinds of factories [36], prisons [37], and social events [38]. Between communities, the virus spreads by people traveling from place to place [39]. There is evidence from China [40], Italy [41], and the US [42] that severe restriction in people's movements both within and between communities was essential for containing the epidemic – something the US did not effectively do. The high rate of transmission, infection, and mortality in the US compared with other similar societies reflects more movement (within and between regions) and social interaction among the public (as the result of fewer

closures of public institutions and spaces), and less consistent use of protective facemasks. (The role of genetic variants is not yet established.) Preceding the hoped-for vaccination program completion, successful response to the epidemic requires communicating and acting upon public health messages at the individual and collective level.

5. Social information

Several existing vulnerabilities in the US stand out for potentially reducing the capacity to generate the public health compliance necessary to change behavior in protective ways. These may include relatively weak science education¹, low investment in public health infrastructure² [45], distrust in scientific authority that correlates with political partisanship [46–48], and political polarization [49]. Here I will focus on one issue: malformations in the information ecosystem that disrupt the dissemination of valuable information and encourage misinformation and disinformation.

In any species- or colony-level defense against an attacking parasite, information is vital, whether at the molecular level of the organism's immune system, or in the social system – as we saw with ants, bees, and other insects, whose colony responses require rapid communication. The human response to SARS-CoV-2 relied on unprecedented data sharing and analysis within the global scientific community, from the initial sharing of the virus genome [50] to the dissemination of epidemiological information through international organizations and public health authorities [51] to genomic surveillance of emerging variants in the pandemic [52]. And scientists shared their reports in preprint form, freely, by the thousands [53]. Of course, if technology makes possible sharing the data and knowledge necessary to combat a pandemic, it also facilitates the rapid population movements that generate global disease spread as well, so the net effect is an information arms race – as occurs in countless cases across biological ecosystems.

¹ The US ranked 13 out of 37 OECD countries on the PISA Science exam in the latest data. Among the countries with higher scores (Estonia, Japan, Finland, Korea, Canada, Poland, New Zealand, Slovenia, United Kingdom, Australia, Germany, and the Netherlands), all had lower per capita GDP in 2018 [43].

² Funding for the Centers for Disease Control and Prevention, which rose 20 percent from 2014 to a peak of \$8.3 billion in the fiscal year 2018, was subsequently cut 8% over the next two years [44].

In the human response, however, the US lagged the information generation and dissemination efforts of peer countries, leading to poor outcomes at the societal (colony) level. The US system fell behind in testing for the infection in the population, in genetic monitoring for virus variants [54,55], and in other areas such as material procurement [56,57]. Unequal and inadequate access to healthcare also set back societal defenses, as in the case of prisons and jails, from which inmates who had been inadequately protected emerged to transmit the virus to their home communities [58]. Although these problems undermined public health efforts, distortions arising from the political system may have been even more consequential.

After the end of the Trump Administration, Deborah Birx, President Trump's White House coronavirus response coordinator, told an interviewer:

"The worst possible time you can have a pandemic is in a presidential election year ... When you have a pandemic where you're relying on every American to change their behavior, communication is absolutely key. And so every time a statement was made by a political leader that wasn't consistent with public health needs, that derailed our response" [59].

The editor-in-chief of *Science* Holden Thorp, reflected: "American science denialism ... persists, even at the highest level of leadership, with a president who denies climate change and a vice president—a devout creationist—who believes that Earth is only 6000 years old" [60]. The political right, led by President Trump and his associates [61], who were primarily concerned with his reelection chances, was able to use an existing anti-science movement infrastructure and media organizations that had been developed as a bulwark against policies to mitigate climate change [62].

The need for clear public health information and communication collided with the political project of President Trump. Authoritarian leaders have historically adopted the mission of discrediting science not so much because of specific issues, but because undermining truth and reason itself creates a vacuum they hope to fill with loyalty to the national leader. As philosopher Jason Stanley writes: "Regular and repeated lying is part of the process by which fascist politics destroys the information space. A fascist leader can replace truth with power, ultimately lying without consequence" [63].

Under the example set by the president, the political right used social media to generate an “infodemic” [64], using unregulated social media platforms designed to amplify echo-chamber information dynamics and promote polarization [65]. The existing health disinformation and conspiracy theory networks quickly retooled to disseminate disinformation about COVID-19 [66]. In the process, the platforms saw rapidly rising market value – Facebook stock rose 31% in value, and Twitter rose 72%, over the year 2020, even as they served pandemic disinformation to hundreds of millions of users. Wide swaths of the US social milieu were primed to distort incoming information in ways that undermine public health: “Users online tend to acquire information adhering to their worldviews, to ignore dissenting information and to form polarized groups around shared narratives” [64]. The conspiracy infrastructure built on social media platforms provided the receptacles onto which the infodemic virus could latch.

After the election, science-denial continued as a dominant theme in the political movement Trump led. One anecdote illustrates the strategy to sow doubt about scientific expertise itself, creating a knowledge vacuum that extends beyond specific public health issues. When White House chief medical advisor Anthony Fauci publicly recommended doubling up cotton facemasks, Representative Jim Jordan, a member of the House Republican leadership with 1.8 million Twitter followers, tweeted, “First, it was don’t wear a mask. Then, it was wear a mask. Now? Wear two masks! What’s next? Shopping in plastic bubbles?”[67]. President Trump had declared Jordan “an inspiration to freedom-loving Americans everywhere,” and awarded him the Presidential Medal of Freedom [68].

6. Conclusion

One question raised by this fact pattern is whether the SARS-CoV-2 virus not only capitalized on US society’s existing vulnerabilities, but also successfully modified US social behavior in ways that exacerbated those weaknesses. In other words, if evolutionary interchanges in biological ecosystems have caused raccoons to become aggressive and spread rabies, and ants to desert their posts to spread fungal spores, did SARS-CoV-2 – acting through social rather than genetic evolutionary means – corrupt US social behavior in

ways that make the society a more hospitable host, and therefore spreader, of the virus? This question is necessarily speculative.

The relationship between humanity and SARS-CoV-2 is unfolding as an iterative sequence of interactions across time and social space. Examining this kind of process in biological ecosystems may hold useful lessons for human society. Millions of viruses “try” to penetrate the human immune system, and those that are successful take advantage of key aspects of our social behavior. But they are also tested at the colony (or societal) level, finding some host environments more hospitable than others. Respiratory viruses are expected to succeed in crowded places, such as Wuhan or Delhi and São Paulo or New York City. However, among the wealthy societies SARS-CoV-2 has thrived especially well in the United States, partly because of deficient and corrupt information management and dissemination systems. In fact, the virus may have trained the US to exacerbate its own weaknesses with regard to the information system.

Table 2 offers a schematic illustration of the comparisons drawn out in this review. Common information dynamics may be seen across nonhuman and human contexts (A). These include the use of information at the individual and social levels, and defenses implemented among individuals as well as colonies – including those with individual reproductive versus (or in addition to) social benefits. Among humans (B), parasites (in this case a respiratory virus) generate behavioral responses at the individual level that, while protecting individuals, also help the virus spread. I have suggested, but cannot prove, that the deficient US response of political polarization around public health information and behavior, may reflects an analogous process. In any event, a successful response requires both individual and social adaptation, and these in turn are conditioned by the information system context. When individuals have adequate science education, receive current information, and trust the authorities that offer advice, they are more successful at resisting infection. That, in turn, may require a social context in which information is equitably distributed and democratically deployed, generate adequate social trust – including an open science environment [69].

Table 2. Information dynamics in nonhuman and human responses to parasitic attack.

	Individual	Social
A. Nonhuman and human		
Information-based learning mechanism	Biological evolution with individual selection	Social evolution with colony selection
Response to specific parasite	Molecular immune response with individual reproductive benefit	Colony defense, with collective social benefit
B. Human		
Host behavior that benefits parasite	Defensive bodily response (cough, runny nose)	Political response for partisan ends (science denial, infodemic)
Information-based defense mechanism	Safety-enhancing personal practices	Public health campaigns
Context for successful information-based response	Science education, access to current information, trust in authority	Egalitarian, democratic information ecosystem with high social trust, open access to science

Humans have a great capacity to adapt and react, evolving much faster socially than biologically – within a lifetime rather than over many generations – partly because we can study how other species adapt over evolutionary time (e.g., how ants fight fungi or bees fight viruses). And we also have the benefit of learning from variation across historical and spatial contexts, so that we can make collective decisions to change our behavior systematically to generate collective defenses. In addition to law and regulation, healthcare, and travel restrictions, a key aspect of this defense occurs in the information ecosystem: public health and science communication. This requires communicating good information, resisting the spread of disinformation, and generating scientific scholarship that is efficient as well as trustworthy. In this respect, a notably successful adaptation has been the acceleration of scientific research dissemination and its democratization on free preprint servers [53] (a development of the global scientific community rather than a US-specific innovation). To the

extent the US fails to rise to this challenge, the result may be seen in a social evolution that weakens US dominance around the world (see, for example, China's much more rapid economic recovery during the pandemic [70]). If the crisis contributes to innovation and reform in the information ecosystem, on the other hand, the result may be not just better defense against this or subsequent biological pandemics, but also a more egalitarian and democratic system for the production and dissemination of knowledge [71].

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