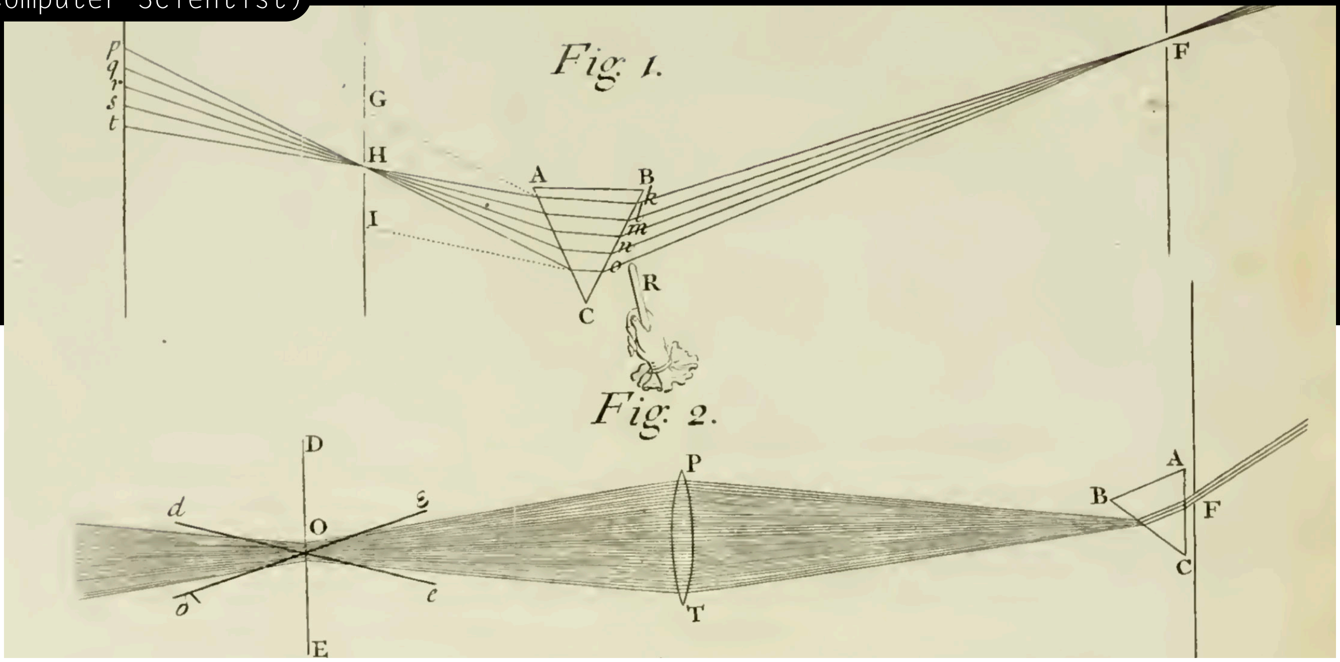
Transmission: Insights on COVID-19

WEEK SEVEN

Welcome back to the *Complexity of COVID-19* course from the Santa Fe Institute. This month's course returns to the theme of insufficient modeling.

Mathematical models of the world are not objective representations of reality because they only capture features that researchers deem salient. Whether in physics, economics, or epidemiology, researchers who create models must make simplifying assumptions in order to broadly understand the system. In the case of an epidemic, modeling the spread of the novel coronavirus as an idealized mathematical process leaves out crucial information about the age, health, occupation, social networks, and socioeconomic status of individuals. When scientists encode their own blind spots into a model, society misses an opportunity to brace the system where it is most vulnerable. And in complex systems, these blind spots have a way of biting back when we ignore them...

In addition to our Transmissions series about COVID-19, SFI has curated a collection of resources from our vast network of researchers that focus on the complex issues of inequality and society, in the pursuit of principles to build a fairer society, which you can find HERE.



If there is one thing that the coronavirus pandemic has exposed, it is that there is much that we still don’t know about the world. Not just on the macro scale of galaxies unexplored, but on the micro scale around and within us. Viruses exist in what is effectively a *hidden world*, teeming with activity, full of blooming, buzzing confusion, competition, and evolution. Sometimes we explore this world intentionally, but more often than not we run into it by accident when the alarms on one of the megafauna bio-detectors — people and animals — go off. Puttering around on the edge of the known and the unknown is the work of science. In 1933, Fritz Zwicky observed a huge discrepancy in the amount of gravitational force that could be attributed to the visible matter in the galaxy. Naturally, he called the solution to this discrepancy “dark matter” — and it was later found that nearly 30% of the universe is made of dark matter. Equally, our understanding of the biological world has been a story of dark matter. Our inability to see at the SCALE of microorganisms early on resulted in the near-mythological origins of disease being “vapors” or “humors”. It was only in 1880 that Robert Koch discovered bacteria, and, in doing so, revealed a material cause for infection.

Of course, we now know that bacteria and microorganisms account for most of the world’s genetic diversity: in the environment at large, and also within our own bodies. Viruses - like the coronavirus - are even smaller than bacteria, and so were also hidden in the dark for some time. They weren’t brought to light until the 19th century, when Dutch microbiologist Martinus Beijerinck (who coined the term “virus”) was investigating the etiology of mosaic disease in tobacco plants. Repeated efforts to culture the source of this disease failed, therefore this thing was unlike bacteria. The cause of this disease, whatever it was, was alive in some ways (it could replicate) but dead in others.

A virus is basically nano-encapsulated genetic information. They have existed from the beginning of biological time, emergent from the proverbial primordial soup, a string of atoms, clumped into molecules, wrapped in another kind of molecular...

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Image: Detail: "bk i, pt ii, plt i" illustration for "Opticks: or a Treatise of the Reflexions, Refractions, Inflexions & Colours of Light", Newton. 1704. Courtesy Boston Public Library.

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...shell, a kind of biological M&M. The raison d'etre of the virus is reproduction, which ironically leaves a fair amount of death in its wake. But really, the virus is an engine of life whose dynamics and mechanisms of existence and reproduction make it the agent of genetic expansion, a "dark life" biological force to the dark energy physical force fueling universal expansion that is dark energy. Not quite twins separated at birth, but siblings separated by several billion years, give or take.

The current thought is that the nucleated eukaryotic cell, upon which all plant and animal life is based, would not exist if not for those original viral infections. In a kind of Nietzschean "that which does not kill us makes us stronger" way, any ability that we now have to fight off some diseases can be partly attributed to viruses that first copied themselves into ancient host genomes. Had jawed vertebrates (all vertebrates but lampreys and hagfish) not acquired genes of viral provenance some 500 million years ago, they would have no ADAPTIVE immune system and thus minimal means of fending off viruses.

Our all-too-human tendency to focus on what is directly or instrumentally visible, or of comparable scale to ourselves, has blinded us to both the largest and smallest scales of the universe — scales where physical forces shape the elementary structure of matter. Maybe now is the moment for us to learn from our microbial allies in the universe of dark matter — the bacteria, from whom we acquire our symbiotic microbiome — that the best way to defeat the dark energy of the virus is to turn its entropic ingenuity against itself, and out-evolve the virus by evolving our scientific ingenuity, and probably our social practices, too. We'll have to adapt; what choice do we have?

READ FULL TEXT

Models Don’t Protect the Vulnerable in Segregated Societies | Melanie Moses (Systems Scientist) & Kathy Powers (Political Scientist)

African Americans are dying from COVID-19 at a rate two to four times higher than white Americans. Per capita cases are higher on the Navajo reservation than in every U.S. state. A myriad of explanations for racial differences in COVID-19 exposure and mortality have been proposed, particularly focused on the work circumstances, living conditions, health status, and healthcare access among African Americans; they tend to live in denser urban areas in multi-generational households, to be essential employees who cannot work from home, are likely to have less paid sick leave and health insurance (but more underlying medical conditions such as diabetes, cardiovascular disease, sickle cell disease, asthma, and exposure to environmental pollutants that elevate mortality risk). A history of unethical medical exploitation (i.e., The Tuskegee Study) has led to a community-level distrust of the medical system, and African Americans are more often turned away or have the severity of their condition underestimated when they do seek help. Similarly, Native American risk is also influenced by extreme inequity in health and economic circumstances, including lack of services as basic as running water and inadequate federal funding of health care. The Native population is a staggering 17 times more likely to be diagnosed and 10 times more likely to die from COVID-19 than the white population in New Mexico (one of the few states reporting sufficient data to make such comparisons).

The current socioeconomic factors correlated with COVID vulnerabilities are themselves the manifestation of hundreds of years of structural racism that has left formerly enslaved and colonized populations with poor physical and economic health in often spatially segregated places. Thus far, epidemic models don’t incorporate these racial and socioeconomic realities into their predictions. Most models still being used in decision making assume “well-mixed” populations — that is, people are modeled like identical balls bouncing randomly in a lottery machine, all equally likely to contract an infection, become sick, infect others, or have their number drawn as the unlucky one to die. However, people are not equally vulnerable, and America is not homogeneous. A complex-systems approach to addressing past inequities would consider historical, layered, and interacting factors that may be impossible to disentangle, but which collectively put certain populations at highest risk.

READ FULL TEXT

Image: Battiste Good’s (Wapostangi) Winter Count, “The eruption and pains in the stomach and bowels; smallpox used them up winter.” Courtesy National Anthropological Archives, Smithsonian Institution.

There is a magic number in epidemic modeling (R_0, the average number of new infections each existing case will produce, which you may remember from previous weeks). When R_0 exceeds 1, new infections grow exponentially — and when it is below 1, the virus succumbs to exponential death. The natural value of R_0 for COVID-19 in a naïve population appears to be above 2. Strong and effective mitigation efforts have brought R_0 below 1 in countries like Taiwan and New Zealand with relatively inexpensive measures. However, in the U.S., with its large and heterogeneous population and weak central leadership on the issue, suppressing R_0 below 1 is currently extremely costly and likely to remain so for the foreseeable future.

In this regime, where mitigation is extremely expensive but having an exponentially exploding number of cases is also unacceptable, R_0 will remain near 1. If R_0 exceeds 1, then exponential growth quickly leads to unacceptable rates of infection, hospitalization, and death — but as R_0 is suppressed by the crude tools of social distancing and business closures, the economic pain creates great pressure to open up the economy, pushing R_0 back above 1. The combination of these two forces generically and robustly keeps R_0 close to the critical value of 1. Many current models of the epidemic include both the biology of infection and policy responses in more or less detail (for example, see figure [2] in the Full Text) but it is useful to understand that these models will display the general feature of **SELF-ORGANIZED** criticality so long as the two strong and opposing forces are incorporated.

One can expect R_0 to stay near 1 and the number of new cases to stay relatively high for an extended period, but with a lot of unpredictable, and perhaps oscillatory, behavior along the way. The only way out is with an effective treatment, or to dramatically lower the cost of an R_0 below 1 through natural herd immunity, a vaccine, or effective testing and contact tracing.

You can explore Machta's calculations and charts in-depth in the full piece.

READ FULL TEXT

Image: "The Apotheosis of War" by Vasily Vereshchagin. Oil. 1871.

Like human pandemics, plant pandemics are also associated with the coming of the current geological age and first started appearing with the rise of an interconnected world. Some of the first recorded pathogen outbreaks were associated with wheat, as recorded by the Romans. In fact, the Romans had a god/goddess of rust (Robigus/Robigine) because these new pathogens (like the rust plant disease) were so feared. Feasts, processions, and sacrifices in their name were conducted in order to prevent crop destruction and stop future waves of reinfection. Over the past 200 years, the number and severity of plant diseases has increased exponentially. Once a pathogen spreads globally, eradication becomes difficult or even impossible.

Governmental plans to deal with plant pandemics — mainly associated with agriculture — now largely revolve around prevention, response, and recovery. The effort to protect the food supply and human health is largely focused on limiting spread and impact. The "chestnut blight" was one of the first major pandemics in forests, but there are many more that impact wild ecosystems. Dutch elm disease, sudden oak death, *Phytophthora cinnamomi*, and *Armillaria* honey fungus are all pathogens in an age of pandemics with potential to alter ecology and cultures, if not entire civilizations. The parallels between COVID-19 and the 1904 blight of chestnut trees are striking. COVID-19 (caused by the SARS-CoV-2 coronavirus) and chestnut blight (caused by the *Ascomycota* fungus *Cryphonectrica parasitica*) both likely arose in Southeast Asia and were transported via international travel NETWORKS that enabled the pathogens to circumnavigate the globe. Over the course of about a month, both spread rapidly and simultaneously across Europe and North America, causing a broad spectrum of disease, with both infections revealing their presence through several symptoms (with the more stressed and susceptible individuals dying first, as the pathogens more easily blocked and “suffocated” the vascular network), and the collateral damage of both pandemics was remarkable.

For years, the American chestnut tree largely defined American deciduous forests, ranging from Maine to Georgia and west to the prairies. It survived all evolutionary adversaries for 40 million years, but then, within 40 years, it effectively disappeared. Pandemics offer a sobering reminder that no matter how dominant the host or how grand and impressive the ecological or economic impact of a species, the exponential growth of a highly transmissible pathogen can be overwhelming.

READ FULL TEXT

Image: Detail: "An Irish Peasant Family Discovering the Blight of their Potato Store." Daniel MacDonald. 1847. National Folklore Collection, University College Dublin.

COMPLEXITY CARDS

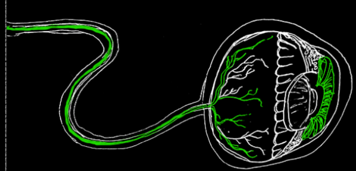
Self Organization

A process in which a pattern at the global level of a system emerges from numerous interactions among the lower-level components of the system, which are acting on local not global information.

Tipping Point

Places where a small change in the input can dramatically affect the outcome, a turning point. A change that likely to leads to additional, often unpredictable, consequences.

Evolvability



The capacity of a system to undergo adaptive evolution.

Life Support Systems Legend

- All Complex Systems
- Architecture, Cities, & Scale
- Astrobiology & Life Detection
- Intelligent Systems & Cognitive Design
- Motion & Energy Technology
- Time Design
- Autonomous Ecosystems
- Social & Economic Engineering
- Planetary Policy, Law & Regulation

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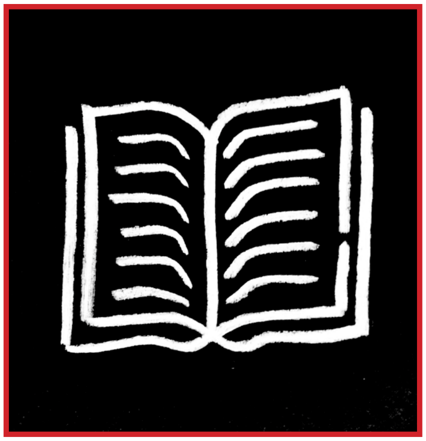
Complexity Podcast: Transmission Series Ep. 7

"Better Scientific Modeling for Ecological & Social Justice"

In the seventh episode of this special supplementary mini-series with SFI President David Krakauer, we explore how the structural inequality created by insufficient models jeopardizes not just those left off the map, but the entire systems in which they participate.

Transmission: Insights on COVID-19 Quiz 7

This weekly quiz will cover topics and details from this week's batch of articles so you can test your knowledge. Included in the quiz are more long-form discussion questions, which we hope will instigate interesting conversations between everyone in your household.



Related Recommendation: Book

Blindness

by José Saramago

The IP team recommends Saramago's chilling tale of a city stricken with a mysterious epidemic. Those infected are forcefully quarantined inside of a heavily guarded asylum, where living conditions start to degenerate quickly. Meanwhile, outside of the asylum, a complete and total breakdown of society unravels.

WARNING: This book contains adult themes.