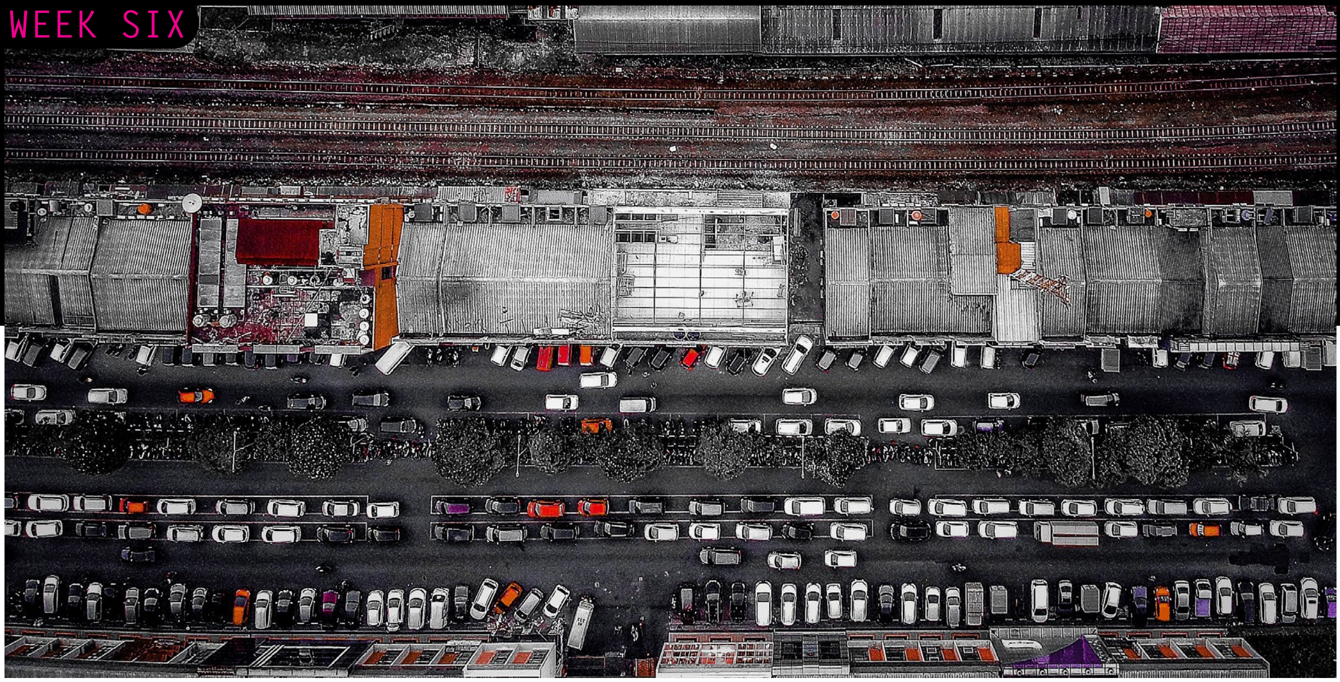
Transmission: Insights on COVID-19

WEEK SIX



Welcome back to the *Complexity of COVID-19* course from the Santa Fe Institute. This week's batch of Transmissions essays speaks to the various ways we can utilize our collective knowledge through technology, history, and well-informed predictive models to assist us through this pandemic.

If COVID-19 has made anything obvious to everyone, it might be how the very small can force the transformation of the very large. Disrupt the right place in a network and exponential changes ripple outward: a virus causes a disease that leads to economic shocks and other social impacts that, in turn, re-open urban spaces to nonhuman animals and change the course of evolution.

Adapting to these changes will require a different kind of understanding: one of nonlinear dynamics, feedback loops, extended selves, and the tiered and interwoven ecological and economic systems of our planet. By studying the processes and structures that this change exposes, we're offered a new way of seeing individuality-in-context...and, perhaps, new mechanisms for aligning individual and public good, the human and the wild.

It is hardly surprising that the vast majority of COVID-19 cases have occurred in cities; after all, more than 80 percent of the world's population lives in dense, urban environments. We should not be surprised that an accidental mutation in a city in China was able to affect huge unemployment in the U.S., the fall of global markets, less pollution in India, and a shortage of yeast in the U.K.

The big question is: to what extent can any of this be quantitatively predictable? Clearly, it involves considerably more than "just" traditional understandings of epidemiology, vaccinology, and health care. How are socioeconomic dynamics such as finance, inequality, neighborhood structure, etc., coupled to the physical infrastructural organization of buildings and transport? We need to fold our thinking about epidemics and similar disasters into a quantitative "Science of Cities." Urban SCALING research has revealed that while cities are highly non-linear, they share surprisingly "universal" commonalities. When a city doubles in size, it's wealth, innovation and social connectivity more than double. The same can be said for darker urban details like crime, inequality, pollution, and disease transmission. While COVID-19 spreads exponentially everywhere, the number of cases in cities grows even faster. And models of social-distancing for settings where people travel alone by car leave out the important fact that in cities, social connectivity is coupled with networks like commerce and transportation.

How does an individual's risk of infection change based on the city or neighborhood they live in? Can urban scaling theory help formulate optimal strategies for aiding cities of different sizes? What can we learn from urban scaling theory that might inform us about trajectories of recovery and what cities and urban life might look like post-pandemic? To what extent can humans live by the internet alone? The short, but incomplete, answer to these questions is that cities are not monochromatic. Comprehensive policies for preparing responses to, and recovery from, a variety of crises should begin by at least taking into account the overall size and underlying network structures of cities themselves.

READ FULL TEXT

Image: "New York" by George Bellows. Oil, 1911."

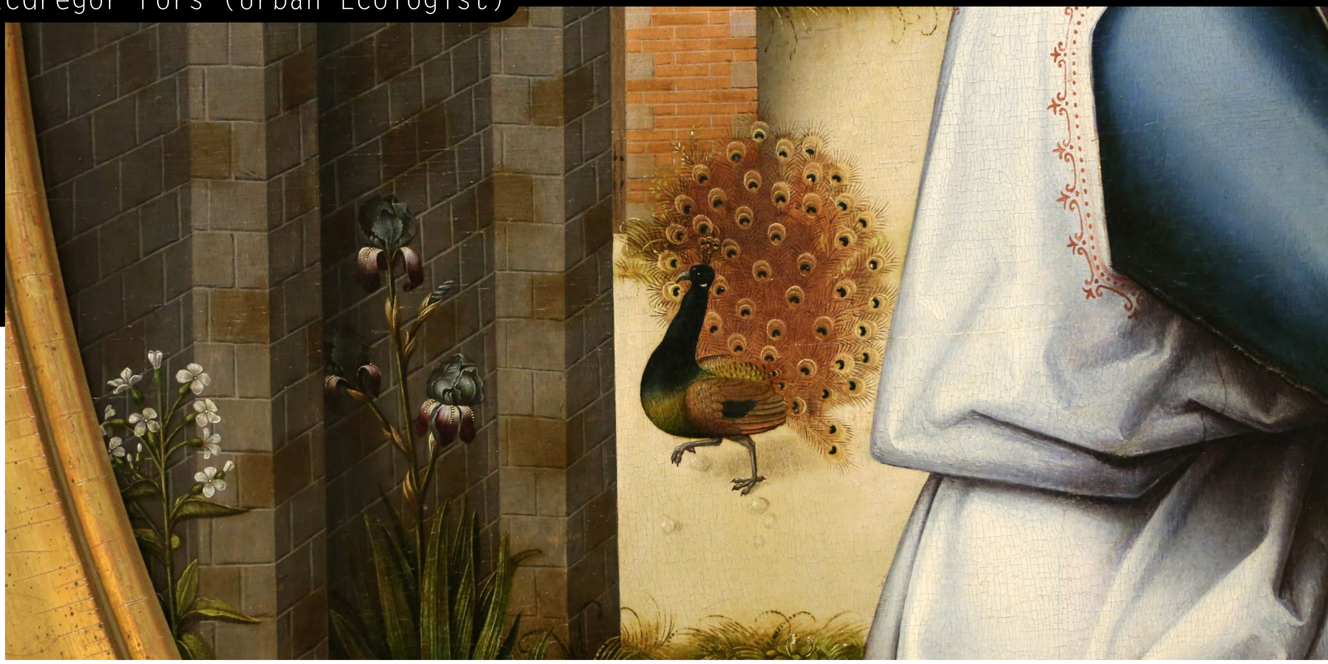
Under normal circumstances, most goods and services are produced, bought, and sold through free markets. But in an emergency like a pandemic, markets may not suffice. Imagine, for example, that society suddenly needs to undertake tens, or even hundreds, of millions of virus tests per week. To whom can we turn to produce the testing equipment? There may be many potential manufacturers, and how can we know who they all are? Even if we know their identities, how do we decide which ones should actually do the producing? How much should each produce? And what price should a producer receive to cover its costs?

If we had the luxury of time, we could expect that the natural flow of supply and demand would equalize to present the consumer with the correct price. In a free market, prices fall if supply exceeds demand, and rises if demand exceeds supply. But if price is too high, because supply is too low, buyers in need are being gouged for goods (tests, masks, etc.). We all benefit from the production of these necessary goods, and we can't wait for the market to titrate to the appropriate price. We must act quickly. In these circumstances, it is of the largest social benefit, and for the greatest benefit of the producer being paid to increase production to a certain level, for the cost of production to be reported truthfully. The way to align social and individual goals is to give individual producers and buyers monetary transfers that transform their personal objectives (profiting) into the social objective (access to life-saving products).

A complete breakdown of market dynamics, and Maskin's calculations leading to this conclusion can be found in the full text. You can find additional insight on this topic on the SFI webinar "Incentives, Levers, and Beliefs".

READ FULL TEXT

Image: "Auctioneer Selling Fish from a Platform to an Excited Crowd" vt M. Prior. Colored Crayon Lithograph, 1870.



The shelter-in-place orders designed to slow the spread of COVID-19 have given us surprising and unexpected sightings of wildlife species in cities around the world. What can seeing all of this wildlife tell us about human-deprived spaces? Some species, including those currently living in cities and those making the occasional forays into them, are now able to use habitats and resources that they had never before been able to exploit. Additionally, species in cities are experiencing less active, less noisy environments (fewer scary humans). As a result of myriad adjustments in a very short period of time, we are experiencing an unprecedented opportunity to study how humans affect other animals in our cities.

A lack of fear can occur in the wild, with a common example in the Galapagos Islands, where many animals, like the Galapagos tortoises, are “fearless” because they have no natural predators. Others, like island lizards flee from the approach of humans. A particularly interesting case exists in the ground finch, which responds negatively to “introduced predators” which have long been exterminated from the islands. This case suggests evolutionary changes related to behavioral response, can occur relatively quickly.

Yeh and MacGregor-Fors have been studying the dark-eyed junco bird, a woodland species that moved from the mountains to college campuses, urban environments and suburban neighborhoods, quite comfortably. Clearly, they don’t fear humans! But how will they respond, both adults living now and offspring born during this “serene” time, to the decrease in human presence? Will they perceive the occasional human as a treat? Will they decrease in FITNESS, or will our absence pass unnoticed? What happens when humans are reintroduced? If many species find our urban environments stressful, should we reconsider how we develop cities?

We keep hearing that “we can’t go back to normal,” in reference to the catastrophic ramifications from this pandemic, but perhaps we can consider how we might more fully share our planet with these animals, when this all passes.

READ FULL TEXT

Image:"Pavone" by Giuseppe venduto a Putifarre, c. 1490-1500. Via Bode-Museum, Berlin.

Exponential Growth Processes | Sidney Redner, Statistical Physicist

One can't help noticing that forecasts of the COVID-19 epidemic's toll are inconsistent with each other, and a single forecast can change dramatically over the course of a few days. Given these uncertainties, one might conclude that none of these estimates are trustworthy. In fact, huge forecasting UNCERTAINTIES are an integral feature of processes that exhibit exponential growth, which refers to a time-dependent process in which the size of [some quantity today] is [its size yesterday], times a [factor that is greater than 1]. $Y = x^n$

Suppose you deposit $1 in a bank that pays 1% interest per day. After one day, your account is worth $1.01; two days later $\$(1.01)^2$, *n* days later $\$(1.01)^n$. Following this, it would take you 1388 days, or roughly 3.8 years, to become a millionaire. If you're at an even more generous bank that pays 10%, it would take just under 5 months. As an important corollary, if you deposited $10, instead of $1 to the 10% interest account, it would take about 4 months to hit one million, meaning the initial value doesn't matter all that much. Let's turn this toward epidemic forecasting, where each COVID patient could infect an additional 2.5 people (R_0 number). That would translate to an interest rate of 250% — meaning the entire planet would be infected after only 25 incubation periods. The goal of social distancing is to reduce this R_0 number to less than 1, but that process is complex and not instantaneous.

In an attempt to model how long it would take mitigation strategies to reduce R_0 to less than 1, Redner creates a scenario where the infection rate drops by a random factor between 1% and 10% daily (so 5% on average). In this way, we see R_0 drop to below 1 at around 18 days, but we also see huge variation in the size of the forecasted epidemic, ranging from 100 times to 10,000 times the initial number of infected individuals. This unpredictability is intrinsic to epidemic dynamics and not indicative of shortcomings in modeling. In short, forecasting ambiguity is unavoidable in exponential growth processes that underlie epidemics.

READ FULL TEXT

Image: "Mount Fuji in the Clouds" by Kimura Tangen, 1753. Kagoshima City Museum of Art.

Landauer's bound is a deep principle of physics, relating to information-processing with the expenditure of energy. Loosely speaking, it says that any physical system must produce more heat if it implements more computation. Among other things, this means that even if you were to use the technology of some far-future civilization to build yourself a new laptop, that laptop would still generate heat when it runs. While Landauer's bound cannot be avoided, it can be circumscribed through a biological idea called extended PHENOTYPE, in which one gets an external system to do one's bidding.

Richard Dawkins emphasized that the concept of "self" can be extended from your physical body to include these other biological systems that you can influence or control. The way this relates to Landauer's bound is that, if you happen to have a biological system around, it's often far easier to get it to perform computation and expend energy on your behalf, rather than do it yourself.

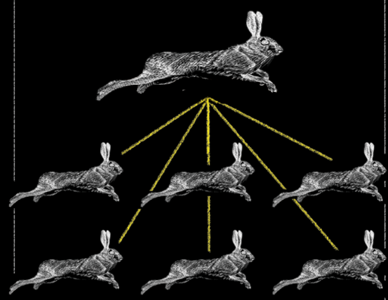
As an example, take the caffeine molecule: coffee wakes up the person drinking it, makes that person engage in many computations that the coffee itself cannot do, and makes them expend a lot more energy than coffee itself can expend. In this sense, waking up a human is part of the extended phenotype of coffee. In the case of COVID-19, the virus is able to bypass Landauer's bound by using its extended phenotype to duplicate itself — and on a far larger scale; not only does a single viral package hijack a human cell, making that cell do its bidding, but the COVID-19 population as a whole also hijacks the entire immune system of the host by inciting symptoms which spread the virus to new hosts. COVID-19's devastation is a prime example of a dramatically successful circumvention of Landauer's bound through the use of extended phenotype. We scientists who investigate the fundamental relationship between computation and energy expenditure can't help but look at it with awe.

READ FULL TEXT

Image: "Long-tailed Cuckoo Young fed by Grey Warbler" by John Gerrard Keulemans for "History of the Birds of New Zealand", 1873.

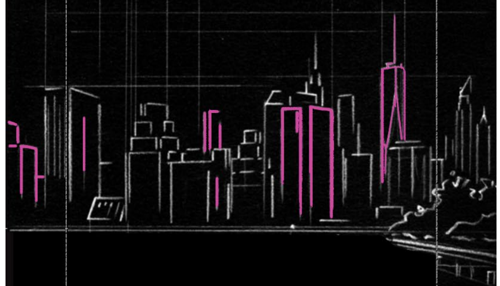
COMPLEXITY CARDS

Fitness



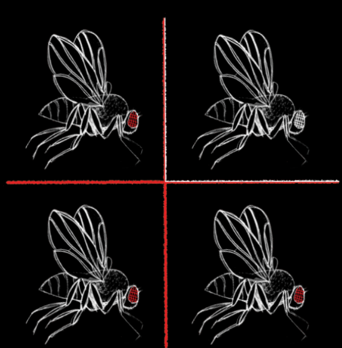
The relative success in transmission of a variant among a population, such as a phenotype in biology, or an idea in culture.

Urbanization



Population shift from rural to urban areas (vertical or horizontal) and its impacts on society and the planet.

Phenotype



Observable characteristics resulting from the interaction of an individual's genotype with the environment, such as morphology or social/cultural behavior.

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

Find out more at www.santafe.edu/COVID19

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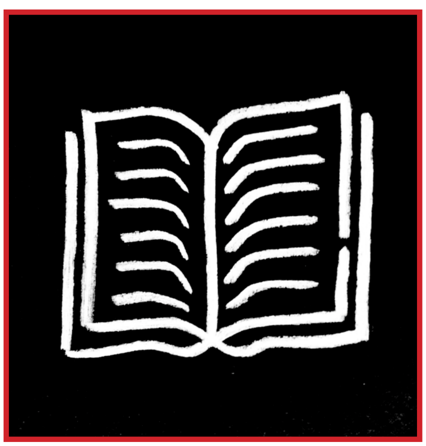
Complexity Podcast: Transmission Series Ep. 6

“Exponentials, Economics, and Ecology”

In the sixth episode of this special supplementary mini-series with SFI President David Krakauer, we explore how adapting to changes incurred during this pandemic will require a different kind of understanding: one of nonlinear dynamics, feedback loops, extended selves, and the tiered and interwoven ecological and economic systems of our planet.

Transmission: Insights on COVID-19 Quiz 6

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

The Ghost Map: The Story of London's Most Terrifying Epidemic — and How It Changed Science, Cities, and the Modern World

by Steven Johnson

The InterPlanetary Team recommends this non-fiction account of a cholera outbreak in London at the height of the industrial age, when a claustrophobic and chaotic urban system enabled devastating results.