

2020

From R_0 to the Herd: A Review of *The Rules of Contagion*, by Adam Kucharski

Nathan D. Grawe

Carleton College, ngrawe@carleton.edu

Follow this and additional works at: <https://scholarcommons.usf.edu/numeracy>



Part of the [Epidemiology Commons](#), [Immunology and Infectious Disease Commons](#), and the [Virus Diseases Commons](#)

Recommended Citation

Grawe, Nathan D.. "From R_0 to the Herd: A Review of *The Rules of Contagion*, by Adam Kucharski." *Numeracy* 13, Iss. 2 (2020): Article 10. DOI: <https://doi.org/10.5038/1936-4660.13.2.1363>

Authors retain copyright of their material under a [Creative Commons Non-Commercial Attribution 4.0 License](#).

From R_0 to the Herd: A Review of *The Rules of Contagion*, by Adam Kucharski

Abstract

Adam Kucharski. 2020. *The Rules of Contagion: Why Things Spread—and Why They Stop*; (London: Profile Books, Ltd.). Hardback ISBN 978-17-88-16019-3. E-book ISBN 978-17-82-83430-4.

Kucharski's well-timed *Rules of Contagion* provides an introduction to the mathematical and epidemiological principles behind contagious phenomenon. While the author's primary expertise stems from work on biological epidemics, the book points to examples from a wide range of fields including finance, psychology, computer science, and criminology. As such, selections of the book could be used by faculty in a wide range of classes to show how our recent experience with a viral epidemic might add to our understanding of a diverse set of questions. While the book points to models behind epidemiological work, those who want an explicit treatment will need to draw that material from other available sources.

Keywords

quantitative literacy, epidemic, public health

Creative Commons License



This work is licensed under a [Creative Commons Attribution-Noncommercial 4.0 License](https://creativecommons.org/licenses/by-nc/4.0/)

Cover Page Footnote

Nathan D. Grawe is professor of economics at Carleton College and the executive editor of *Numeracy*.

The award for best-timed publication of the decade must certainly go to Adam Kucharski, whose *Rules of Contagion* came out at the beginning of this year. Professors looking for ways to tie lessons in quantitative reasoning to experiences connected to the COVID-19 pandemic might consider using parts of this general-interest book to motivate discussion.

Written before “coronavirus” became a household word, the book makes no mention of the current virus. Still, in a reminder that there is nothing new under the sun, readers will find many familiar concepts: R_0 , *herd immunity*, *variolation*, *second waves*, *phylogenetic analysis of virus mutations*, and even *social distancing*—a phrase that may have been new to most of us but not to epidemiologists.

Kucharski begins with Ross’s (1897; 1910) seminal work on malaria. While many may view the key insight from this work to be biological—the observation of malaria in the midguts of mosquitoes—Kucharski and Ross himself perceive a very different contribution. As Kucharski explains, “most physicians thought about malaria in terms of descriptions: when looking at outbreaks, they dealt in classifications rather than calculus. But Ross was adamant that the processes behind disease epidemics needed to be quantified” (21).

Perhaps more to the point, Kucharski notes that, unlike contemporaries who used quantification to merely describe the extent and progression of an epidemic, Ross discovered the power of formal mathematical models of the mechanism of transmission (17–18). Such models could do much more than merely describe a progression; they might suggest ways to fight an epidemic. For example, Ross considered the case of a village of 1,000 inhabitants beset by 48,000 mosquitos. Should we expect malaria to propagate from a single infection? Ross reasoned that not all mosquitos would bite a human, and if only one in four did, we would expect 12,000 total bites, of which only 12 would involve the infected person. Perhaps one-third of the responsible mosquitos—a total of 4—would survive long enough to be capable of passing malaria on to a new bite victim. If again only one-fourth of mosquitos bite a human, on average only one of these insects would pass on the infection. In this case, the epidemic might proceed but only just.

While the mathematical tools involved in this argument are modest, the insight is tremendous. Control of malaria epidemics did not require the elimination of all mosquitos. We simply must reduce the population below some threshold, and we will prevail. Of course, because chance is lumpy, some epidemics may last a little longer than others, but if the number of mosquitos remains below the threshold, before long the laws of probability reach an inevitable conclusion.

While Ross’s application was to malaria, the power of mathematical models lies in their potential for transference. For example, Kucharski explains how the same model permits us to calculate the infection rate necessary to achieve herd immunity—that is, what fraction of the population must carry antibodies so that an

infection can be expected to peter out rather than create a sustainable epidemic. The process begins with the reproductive number R , which measures the expected number of new infections generated by an original infection. To make the example concrete, Kucharski considers an infection with $R=5$ (56–57). In an unvaccinated population, a single infection leads to five more sick people which might then spread the disease to 25 more, and an epidemic is soon out of control. However, Kucharski notes that if 80% of the population were immune, then four-fifths of those exposed would not acquire the disease, so the number of newly infected would fall to just one. The virus would barely succeed in reproducing, so herd immunity would be achieved after the infection rate climbs over 80%. A less effective virus might run into the barrier of herd immunity at much lower rates of infection.

Given the importance of R , epidemiologists have analyzed its determination with the DOTS model (58):

$$R = \textit{Duration} \times \textit{Opportunities} \times \textit{Transmission probability} \times \textit{Susceptibility}$$

where *duration* is the length of time a person is infectious, *opportunities* represent the number of daily contacts the infected person has, *transmission probability* captures the likelihood any contact passes on an exposure, and *susceptibility* notes the share of the population capable of being infected. As we have learned in recent months, outbreaks can be combatted on all four fronts—through quarantines, stay-at-home orders, social distancing, and vaccines (to name just four approaches, one for each element of the model, respectively).

As Kucharski explains, these basic understandings of viral transmission have been deepened by recent application of network theory. For example, the progression of an epidemic will be vastly different if everyone is connected to everyone else—though at varying degrees of separation (a “fully-connected network”)—than if a community is composed of a number of separate subnetworks that are disconnected from each other (a “broken network”) (63). Similarly, contagion can be affected when a network is composed of links spread more or less uniformly about the population (“assortative networks”) rather than being made up of a series of connected hubs with spokes (“disassortative networks”) (75). (Fig. 1 provides examples of these four network types.) Clearly, models that account for such network features are a vast improvement on those that assume random interactions.

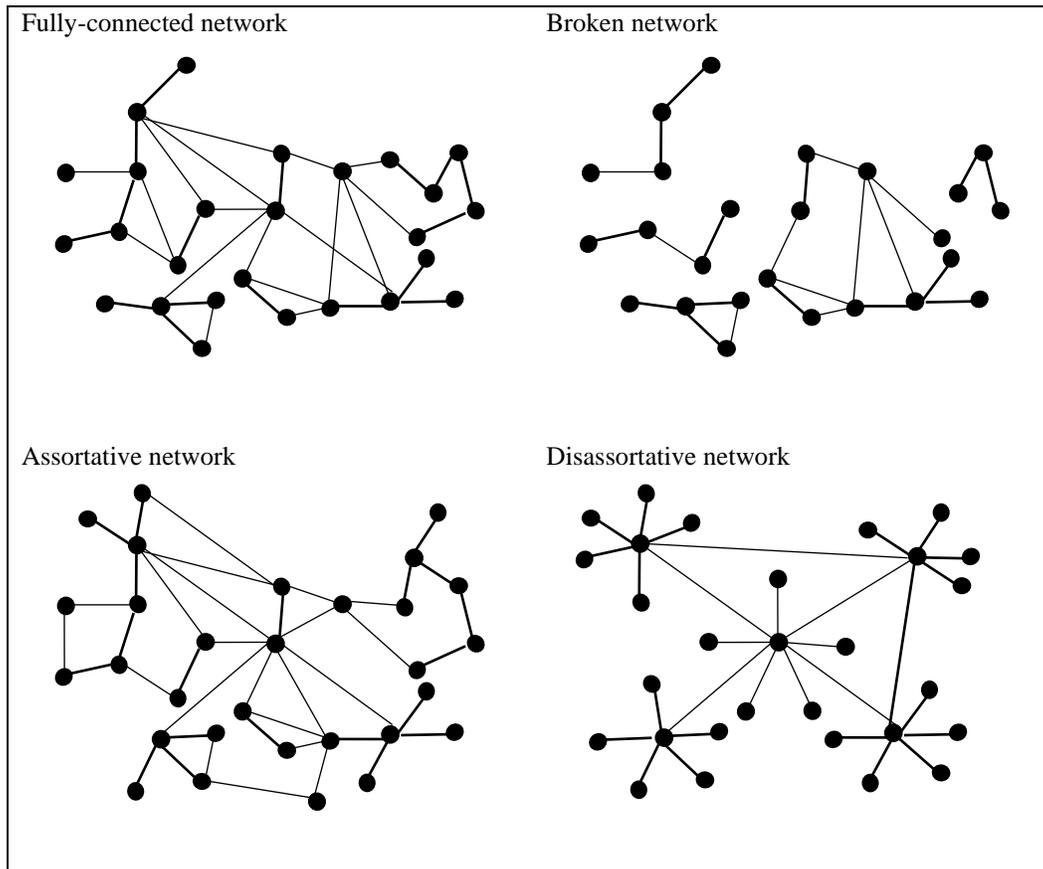


Figure 1. Examples of networks of various types.

While the book draws heavily (in a good way) on examples from epidemiology, its real thesis is that quantitative tools don't belong to any particular discipline. Kucharski, a mathematician by training and a practitioner of epidemiology, sees potential for understanding a wide range of phenomena using the models developed to understand disease transmission. Case studies, which make up most of the book, include applications to computer malware, financial crises, crime, marketing campaigns, the spread of ideas, emotional states, online echo chambers, and linguistics.

As I read the examples related to finance (chapter 2) through the lens of my own discipline (economics), I found myself having a number of doubts. Indeed, one of my field's primary contentions is that people are not deterministic—they are rational, so biological models like the DOTS framework miss important ways in which people decide whether to be “infected”—both literally when studying health economics or metaphorically as when considering financial crisis. (See Gersovitz and Hammer [2003] for an introduction to the economics of epidemiology.) Ironically, what frustrated me with Kucharski's analysis was the lack of explicit

models, relying instead on handwaving that effectively swept many challenging (and interesting) questions under the rug. My mind kept objecting, “But it is more complicated than that! You are making large and questionable assumptions. Do you know that?!” I wondered if experts in other fields examined in the book would have raised similar objections when their area was under the microscope.

Based on Kucharski’s early experience in finance, I expect he knows exactly what he’s doing. It’s just that there is only so much mathematical rigor one can work into a book of this nature. Moreover, he writes very explicitly about the potential pitfalls that follow from seeing nails everywhere when one holds a hammer. “In reality, it is very difficult to find simple laws that apply in all situations We need to work out [the] limits” of our theories (111).

Because the book does not provide expressions for many of the models, some who want to teach with it will want to supplement. One obvious place to start would be the SIR—Susceptible, Infected, Recovered—model (Kermack and McKendrick 1927). I have also found the explanation in Battacharya et al. (2013) accessible and useful to students with a range of math experience from algebra up to differential equations.

Kucharski also cautions us against becoming so enamored of our quantitative (clean) models that we lose sight of the very social (muddy) underpinnings. For example, he points to predictive crime models that purportedly facilitate policing practice without the taint of bias and discrimination. Of course, the models are typically trained on prior data generated by imperfect human processes with all that entails (153). It is difficult to read this analysis and not see the important contributions of sociologists who remind us that data are socially constructed. (See Best [2020] in this issue.)

In each chapter, the book’s value is made even greater by a list of suggested readings for those who would like to go deeper. While the breadth of the book might make it difficult to adopt as a primary text for any one course, it is easy to imagine using it as a jumping off point for modules in courses across the curriculum including: economics, business, psychology, statistics, biology, linguistics, computer science, criminology, political science, and sociology. By engaging the idea of contagion outside the biological realm, students have a chance to think about questions relevant to the transformative public experience they have lived through without augmenting virus-fatigue by applying these notions directly to COVID-19.

References

- Battacharya, Jay, Timothy Hyde, and Peter Tu. 2013. *Health Economics*. New York: Palgrave Macmillan.
- Best, Joel. 2020. “COVID-19 and Numeracy: How about Them Numbers?” *Numeracy* 13(2): Article 4. <https://doi.org/10.5038/1936-4660.13.2.1361>

- Gersovitz, Mark, and Jeffrey S. Hammer. 2003. "Infectious Diseases, Public Policy, and the Marriage of Economics and Epidemiology." *World Bank Research Observer*, 18(2): 129–157. <https://doi.org/10.1093/wbro/lkg011>
- Kermack, William Ogilvy, and A. G. McKendrick. 1927. "A Contribution to the Mathematical Theory of Epidemics." *Proceedings of the Royal Society of London. Series A*, 115(772): 700–721. <https://doi.org/10.1098/rspa.1927.0118>
- Ross, Ronald. 1897. "On Some Peculiar Pigmented Cells Found in Two Mosquitoes Fed on Malarial Blood." *British Medical Journal* 2(1929): 1786–8. <https://doi.org/10.1136/bmj.2.1929.1786>
- Ross, Ronald. 1910. *The Prevention of Malaria*. New York: E. P. Dutton & Company.