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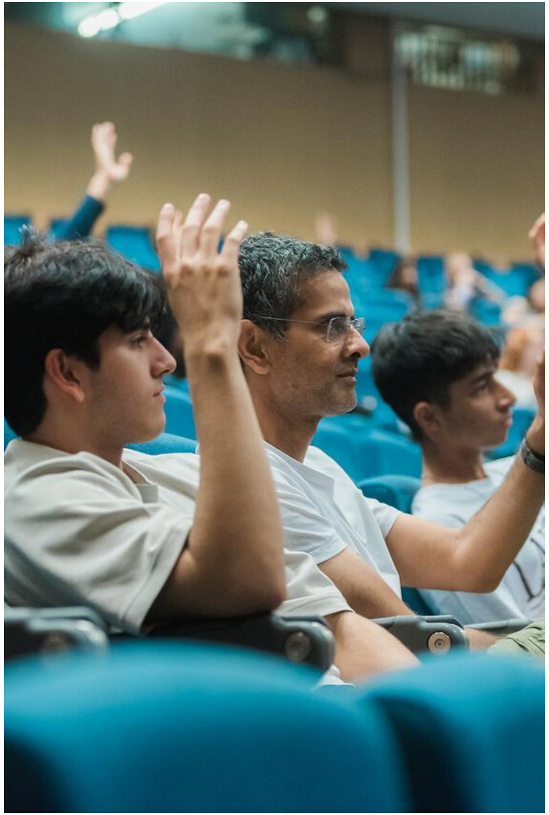
Stochastic Processes for the Masses

Inspiration for an interactive introductory lecture suitable for open days, non-specialists and beyond

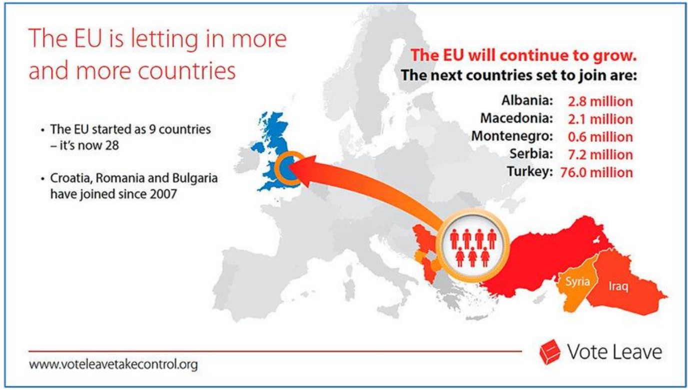
INTRODUCTION

- Need to inspire students
  - Interactivity, real-world examples
- Students can have limited maths background
  - Open days, service courses
- I’d like to provide an example of a session I’ve run

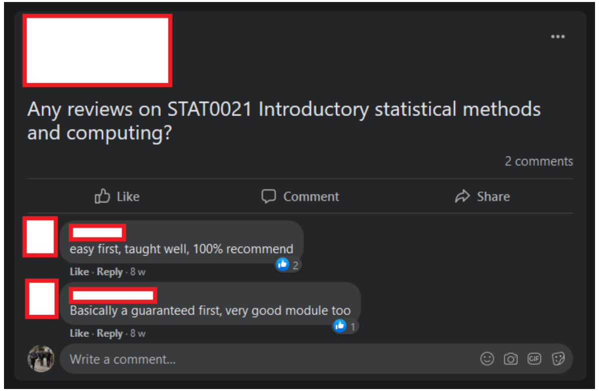


SCENARIO

- Spread of misinformation online
  - A problem for social media companies? Governments?



Sykes, Olivier. 2018. "Post-Geography Worlds, New Dominions, Left behind Regions, and 'Other' Places: Unpacking Some Spatial Imaginaries of the UK's 'Brexit' Debate." *Space and Polity* 22 (2): 137–61. doi:10.1080/13562576.2018.1531699.



The FLAT EARTH SOCIETY

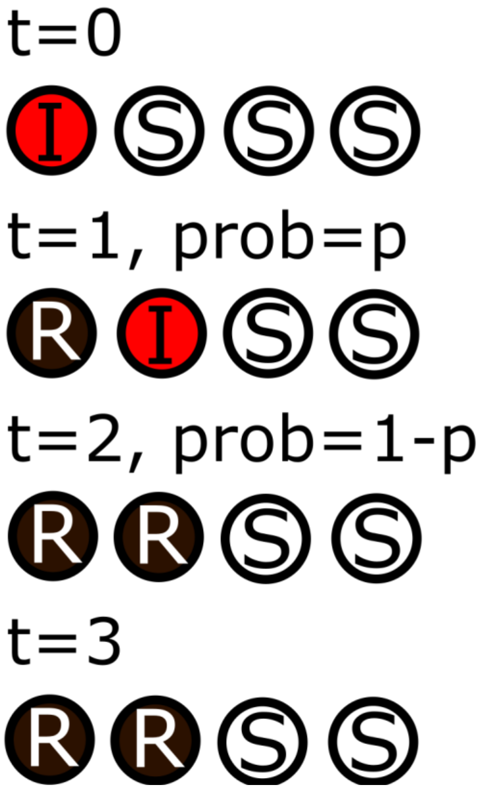
https://wiki.tfes.org/images/3/3f/Flat_Earth_Society_Logo.png

MODELLING

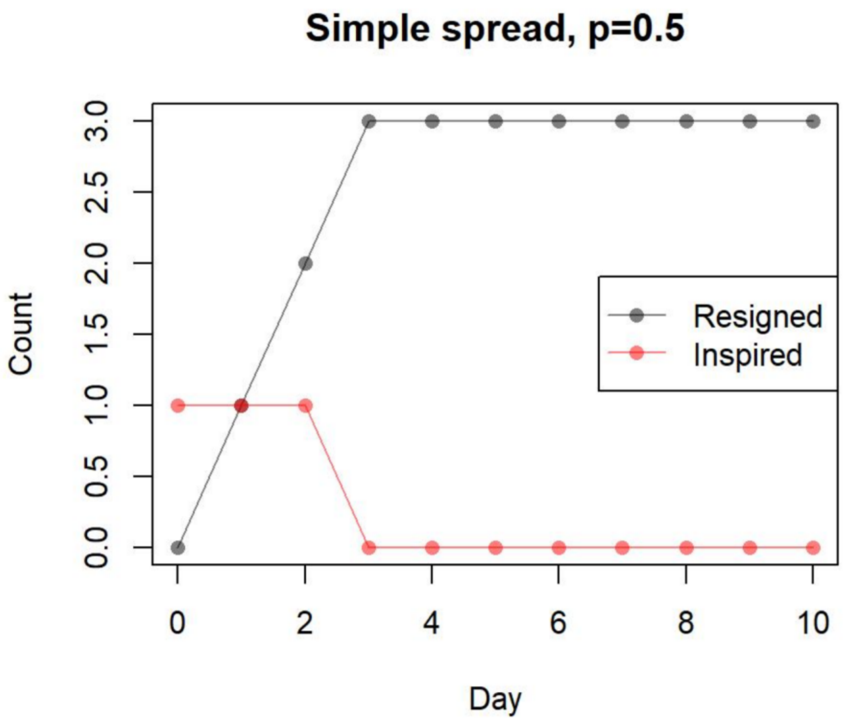
- Sensible
  - Not exposed to misinformation
- Inspired
  - Exposed to misinformation
  - Inspired to spread the message
- Resigned
  - Resigned to the new “truth”
  - Not actively spreading

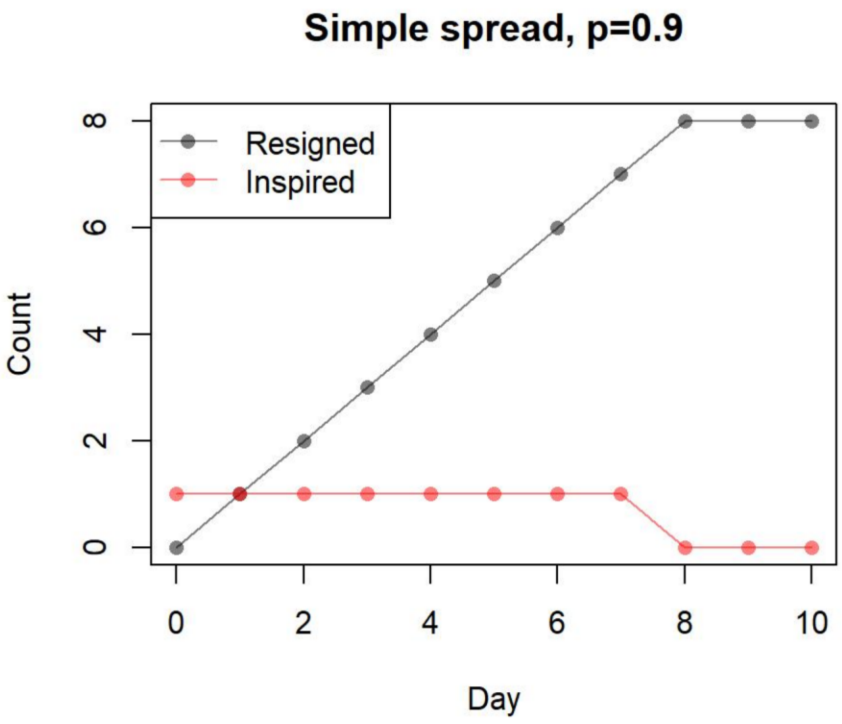
EXPLORATION

- $t = 0$
  - 1 inspired
- $t = 1$
  - Inspired converts 1 Sensible to Inspired with probability $p = 3/4$
  - “Old” Inspired becomes Resigned
- $t = 2$
  - Repeat



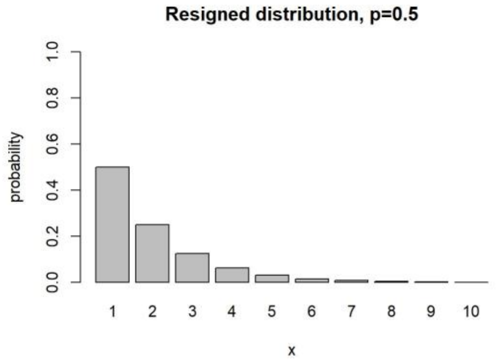
VISUALISATION

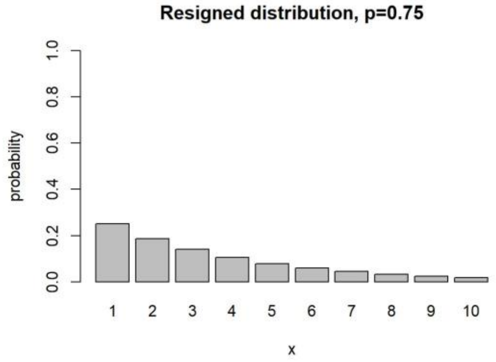




SOLUTION

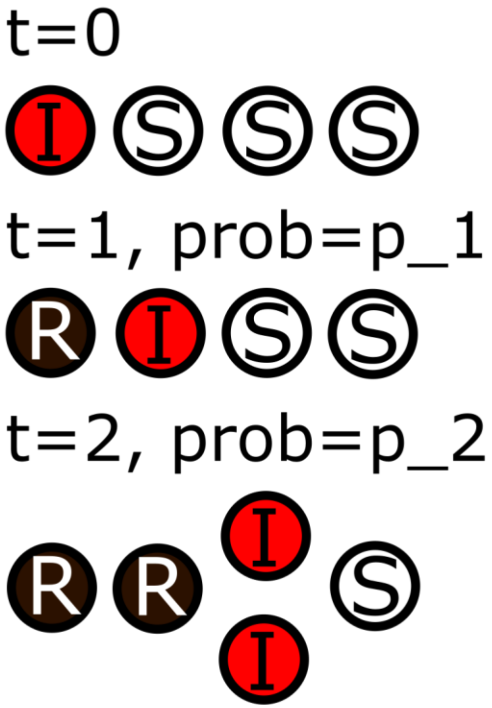
- X: Final number resigned
- $P(X = x) = p^{x-1}(1-p)$
  - $x = 1, 2, 3, \ldots$
- $X \sim Geometric(p)$
  - $mean(X) = \frac{1}{1-p}$
- Spread will always end



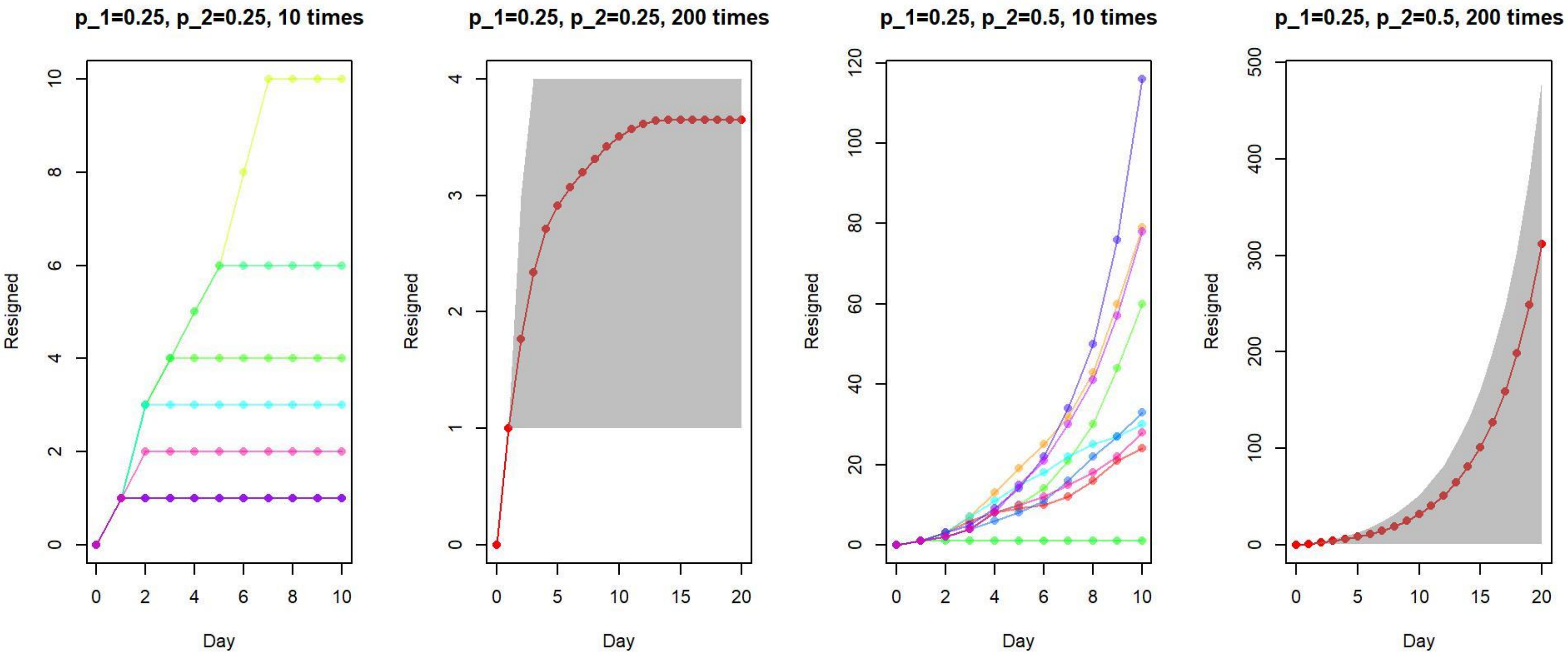


COMPLICATION + EXPLORATION

- $t = 0$
  - 1 inspired
- $t = 1$
  - Each Inspired converts 1 Sensible to Inspired with probability $p_1 = \frac{1}{4}$, 2 Sensible to Inspired with $p_2 = \frac{1}{4}$
  - “Old” Inspired become Resigned
- $t = 2$
  - Repeat (then try $p_2 = 1/2$)

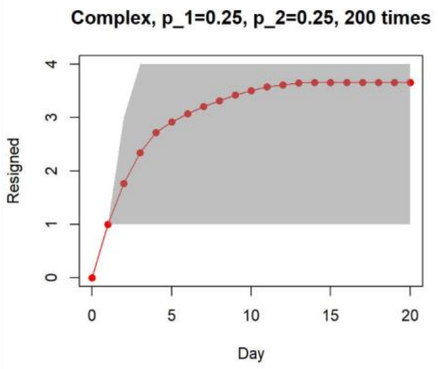


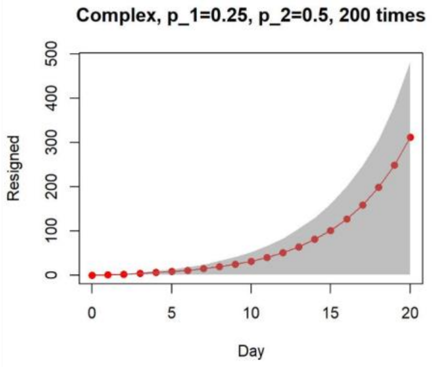
VISUALISATION



DISCUSSION

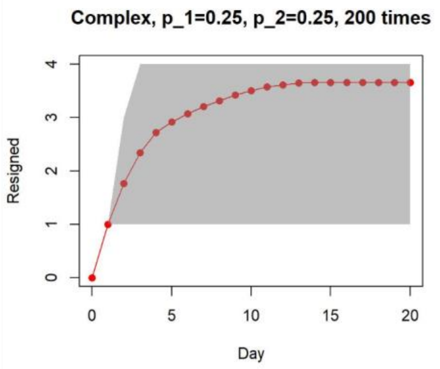
- When do we lose control?
- $p_1 + p_2 > \frac{1}{2}$?
  - No, $p_1 = \frac{3}{4}$, $p_2 = 0$
- $p_2 > p_1$?
  - No, $p_1 = \frac{1}{100}$, $p_2 = \frac{2}{100}$
- Perhaps consider $p_1 = 0$
  - $p_2 > ???$

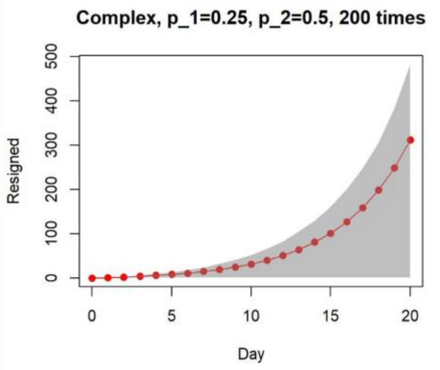




SOLUTION

- Reproduction number, R
  - Average newly Inspired for each previous Inspired
- $R = 1 \times p_1 + 2 \times p_2$
  - $p_1 = \frac{1}{4}, p_2 = \frac{1}{4}, R = \frac{3}{4}$
  - $p_1 = \frac{1}{4}, p_2 = \frac{1}{2}, R = \frac{5}{4}$
- Behaviour change at $R = 1$



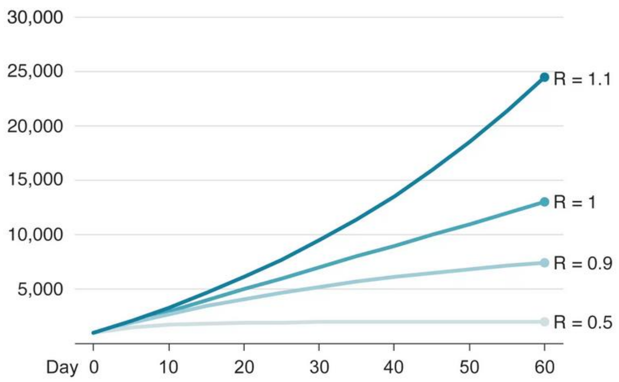


REVELATION

Coronavirus: What is the R number and how is it calculated?

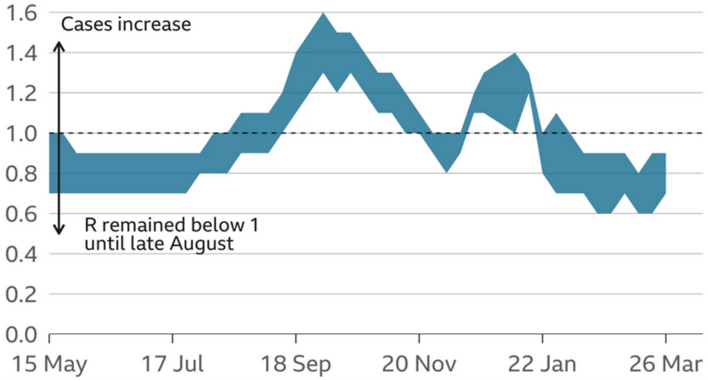
26 March 2021 · Comments

How 1,000 cases would increase under different infection rates



How R has changed over time

Upper and lower R estimates, updated weekly since May



https://www.bbc.co.uk/news/health-52473523

Susceptible

↓

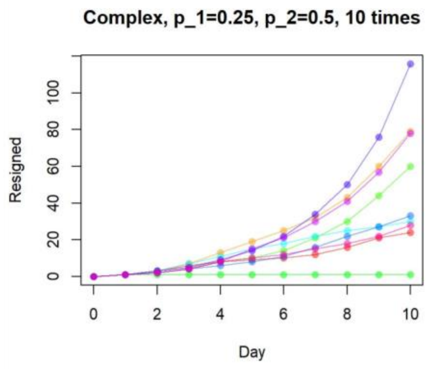
Infected

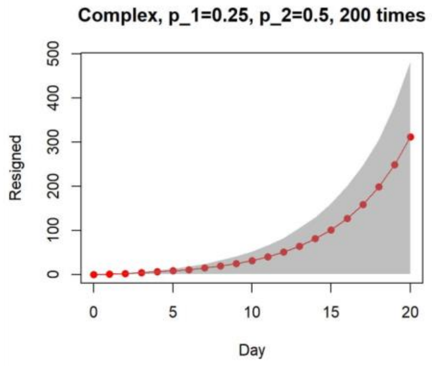
↓

Removed

ILLUMINATION

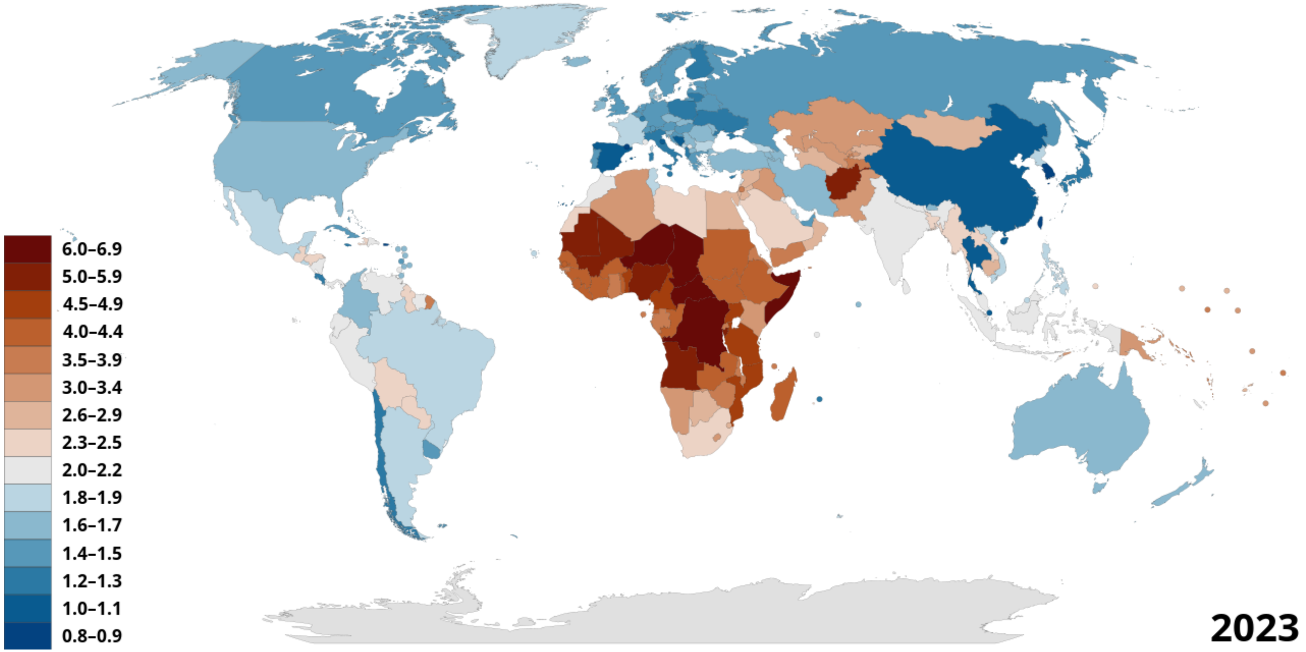
- Similarities between the spread of misinformation and infectious diseases
- Simple models can lead to complex behaviour
  - Benefits of computer simulations
- Interest in averages
  - Also, reasonable best/worst cases





EXTENSION 1

- Total Fertility Rate



https://en.wikipedia.org/wiki/File:Total_Fertility_Rate_Map_by_Country.svg

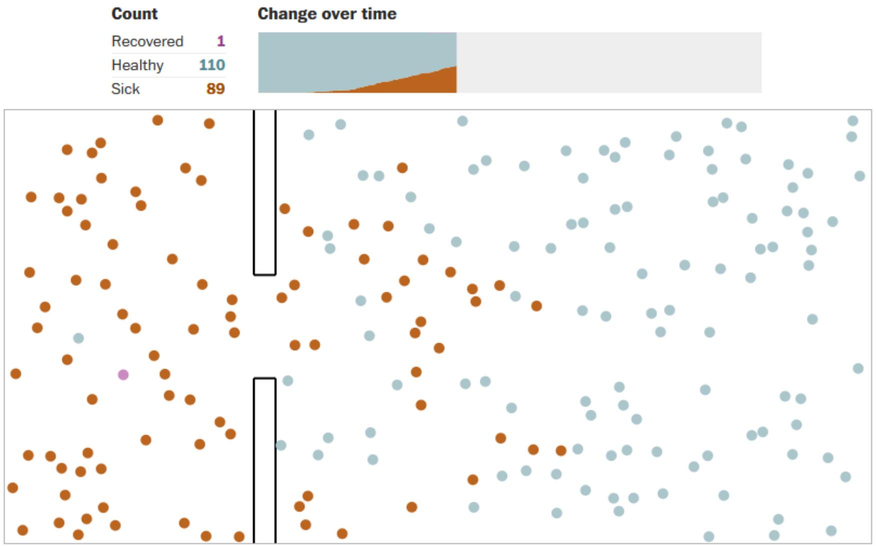
EXTENSION 2

- Develop stochastic process theory
- Replicate (and extend) computer simulations

Health

Why outbreaks like coronavirus spread exponentially, and how to "flatten the curve"

By Harry Stevens March 14, 2020



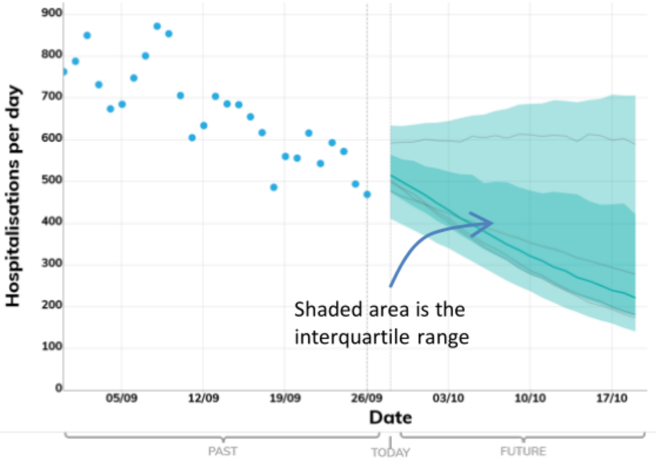
https://www.washingtonpost.com/graphics/2020/world/corona-simulator/

- Acknowledge contributions of Statistics

SPI-M-O
Medium-Term Projections

29th September 2021

ENGLAND



Annex: SPI-M-O Vaccine Effectiveness Assumptions

Table 1: Vaccine reduction in risk of hospitalisation or death [3]

		Imperial [2] (Death)	Imperial [2] (Severe disease)	Manchester [1]	Warwick [2,5] (Death)	Warwick [2,5] (Hospitalisation)	PHE/ Cambridge [2]	Scottish Government [2]
Pfizer-BioNTech	1 Dose	85%	85%	75%	90%	90%	78%	80%
	2 Doses	95%	95%	75%	98%	98%	97%	95%
Oxford-AstraZeneca	1 Dose	80%	80%	75%	81%	81%	78%	80%
	2 Doses	95%	90%	75%	95%	94%	97%	95%
Moderna	1 Dose	85%	85%	75%	90%	90%	78%	80%
	2 Doses	95%	95%	75%	98%	98%	97%	95%

Table 2: Vaccine reduction in risk of infection [3]

		Imperial [2]	Manchester [1]	Warwick [2,5]	PHE/ Cambridge [2]	Scottish Government [2]
Pfizer-BioNTech	1 Dose	33%	75%	56%	31%	55%
	2 Doses	85%	75%	80%	80%	75%
Oxford-AstraZeneca	1 Dose	33%	75%	34%	31%	40%
	2 Doses	58%	75%	64%	80%	65%
Moderna	1 Dose	33%	75%	56%	31%	75%
	2 Doses	85%	75%	80%	80%	85%

Table 3: Vaccine reduction in onward transmission, in addition to reduction from lower infection risk [3]

		Imperial [2]	Manchester [4]	Warwick [2,5]	PHE/ Cambridge [2,4]	Scottish Government [2]
Pfizer-BioNTech	1 Dose	40%	-	45%	-	29%
	2 Doses	40%	-	45%	-	40%
Oxford-AstraZeneca	1 Dose	40%	-	45%	-	37%
	2 Doses	40%	-	45%	-	44%
Moderna	1 Dose	40%	-	45%	-	29%
	2 Doses	40%	-	45%	-	40%

https://www.gov.uk/government/publications/spi-m-o-medium-term-projections-29-september-2021

Thank you for listening

I’m happy to take questions now, and chat throughout the conference

(I’ll collect the dice 😊)